# Cephalometric Evaluation of Mandibular Relapse Following Bilateral Sagittal Split Osteotomy

**Norman Richard Hing, B.D.S. (Syd.)**

**Oral and Maxillofacial Surgery**
**Faculty of Dentistry**
**The University of Adelaide**
**South Australia**

**1989**

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## SUMMARY


A retrospective cephalometric investigation was performed to evaluate early, intermediate and long term postsurgical relapse following mandibular advancement by the modified bilateral sagittal split osteotomy.

The investigation involved a detailed assessment of 40 serial cephalometric records. Twenty patient records had longitudinal radiographs which had been taken a minimum of two years after surgery. This subset was investigated for long term relapse.

The forty records were assigned to one of four groups. Group 1 consisted of bilateral sagittal split osteotomy stabilised with screw fixation. Group 2 were cases with bilateral sagittal split and Le Fort I osteotomies stabilised with screw fixation. Group 3 consisted of bilateral sagittal split osteotomy stabilised with wire fixation. Group 4 were cases with bilateral sagittal split and Le Fort I osteotomies stabilised with wire fixation.

Relapse was measured over the short, intermediate and long term and correlated with selected cephalometric variables. The results of the short term study showed that there were no significant differences between sexes for any of the variables studied. In addition, no statistical differences were shown between groups 1 and 2, nor between groups 3 and 4. Therefore, the screw fixation and the wire fixation subgroups were combined. When the groups were examined according to the method of fixation, relatively minor differences between the screw (SF) and wire (WF) fixation groups were evident in the first 6 weeks following surgery. Relapse appeared to be associated with the amount of surgical advancement but this correlation could have arisen through topographical associations independent of a true biological effect.

Early relapse was not correlated with the preoperative mandibular plane, altered posterior facial height or gonial angle. A clear association between condylar displacement and early relapse tendency was not shown in either group. It was found that gonial arc radius increased for both groups in 26 of the 40 (65%) cases but returned by 6 weeks, including those patients in intermaxillary fixation. The high rate of condylar displacement may have been the result of a limitation in surgical technique or a cephalometric misinterpretation.

Both groups had comparable mean mandibular advancement but the relapse tendency was higher in the SF group (-20.3%). This level of relapse conflicts with previous investigations on the stability of screw fixation Early relapse in the WF group was -13.6% but this difference, compared with the SF group, did not reach statistical significance.

The most significant difference ($P < 0.005$) between the fixation groups was the surgical increase in gonial angulation for the WF group. This was almost double the change recorded for the SF group. The increase in gonial angle for the WF group related more strongly to increased anterior facial height with a lesser contribution from proximal rotation. Despite this difference, no association with relapse was noted. Dental compensation during the first six weeks (T2-T3) was not conspicuous in either group.

In view of the finding that condylar position was not a primary determinant of relapse, it would appear that other factors encourage early relapse. It is possible that the introduction of a new surgical technique, such as screw fixation, inevitably involves a learning phase where intraoperative compromise may occur. Thus the consequences of accepting small compromises in occlusion may not be apparent until cephalometric studies are embarked upon.

The results at 12 months confirmed the findings of previously published research that mandibular relapse continues into the intermediate period. In the long term, stability was observed for all variables implying that 12 month's observation is a minimum requirement for long term studies.

The data from this study showed a mean percentage relapse of -32% after one year. Approximately half of the relapse (-17%) occurred in the first six weeks and the remainder occurred over the next ten months. Intermediate relapse appeared to be correlated with the amount of surgical advancement in the mandible when all subjects were included. This association was slightly stronger in the wire fixation group compared to the screw fixation group. Notwithstanding specious associations, a biological effect appeared to be involved, supporting the contention that the greater the initial surgical advancement, the greater the likelihood of postsurgical relapse within one year.

No single factor, with the possible exception of magnitude of advancement, was consistently responsible for intermediate relapse. The commonly discussed factors such as preoperative mandibular plane angle, altered posterior facial height and altered gonial arc radius did not appear to influence the amount of relapse when the total sample was assessed.

An interesting trend was observed between chronological age for males and intermediate relapse at B point. It is postulated that the compensatory effect of growth in the small male sample helped to mask postsurgical relapse. This aspect could be confirmed by a cephalometric study of males aged by hand-wrist radiographs, to determine whether this trend represents a true association with decreased relapse tendency.

The validity of these results was confirmed by quantifying the error of the method. Double determinations were carried out on 10 cephalograms from 3 randomly selected cases. Under standardised conditions, twenty hard tissue points and 2 fiducial points (x and x′) were digitised on a *Hewlett Packard* 9874A digitiser configured to an *Apple IIe* computer.

The results were expressed as the mean of the differences, the standard error of the mean differences, the standard error of a single determination and the error variance per cent. A rank order based on the standard error of a single determination was assigned to each variable in the $x$ and $y$ plane. Scattergrams were compiled to illustrate the differences between the first and second determinations and each cephalometric point demonstrated a characteristic distribution around origin. The results of this investigation showed that the mean differences and total errors of the method were small. When these were expressed as a percentage of the error variance, errors contributed less than 2 per cent of the observed values.

The total error for 9 angular and 4 linear measurement was established using a modification of the method described by Will et al. (1984). Ten films were traced, superimposed and digitised on 4 occasions giving 20 double determinations. Investigation of the total error for the 13 variables showed that five angles and two linear values differed at the 5% level of probability. However, the mean differences and standard error of the mean differences were small and none of the angles or distances exceeded 1° or 1 mm for the standard deviation of a single determination. The percentages of the observed variance attributable to errors were low for all angular variables. Of the linear variables, overjet and overbite displayed the largest values of 4.52% and 2.55% respectively. It was concluded that the total experimental error was small and was therefore unlikely to contribute significantly to the observed results.

# STATEMENT

This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Dental Surgery. I declare that the text of this thesis has not been previously published or written by another person except where due reference is made. The findings are the result of my personal investigations. No part of this work has been previously submitted for a degree in any university.

Norman Richard Hing, B.D.S.
The University of Adelaide,
October, 1989.

## ACKNOWLEDGEMENTS

I wish to acknowledge the guidance offered by my supervisors, Professor Tasman Brown and Dr. Alastair Goss. Professor Brown devoted many hours to ensure the smooth operation of the computer programme and offered constructive criticism during the preparation of this thesis.

I am grateful to Dr. Goss for his selfless assistance and interest throughout this study. He was readily available for discussion and provided helpful guidance whenever the situation arose.

I wish to thank the consultant surgeons and surgical registrars of the Oral and Maxillofacial Surgical unit. Professor Henk Tideman was particularly encouraging during the formative stages of this study and I am indebted to him for imparting his knowledge and enthusiasm.

The enduring help and patience shown by the Oral and Maxillofacial nursing and reception staff, the secretarial staff in Dental administration and the department of Radiology, Adelaide Dental Hospital earn my eternal thanks. I am particularly indebted to Dr. Ian Stead, Chief Executive Officer, Adelaide Dental Hospital, who provided freely of his time, ingenuity and word processing facilities. The work carried out by the Department of Orthodontics, Adelaide Dental Hospital, is also gratefully acknowledged.

Appreciation of the postoperative care administered by the nursing staff of the Royal Adelaide Hospital is acknowledged. Special thanks goes to Ms. Anna Langen-Zueff, Medical Illustration Unit, the Royal Adelaide Hospital, who provided the superb illustrations throughout the text.

Finally I wish to thank my wife, Sue, for her limitless patience, understanding and love throughout this research.

# I

# Introduction

# CHAPTER 1

## CEPHALOMETRIC EVALUATION OF MANDIBULAR RELAPSE FOLLOWING BILATERAL SAGITTAL SPLIT OSTEOTOMY

The degree and timing of postsurgical relapse following bilateral sagittal split advancement of the mandible has not been resolved. The wide variation in mean relapse values reported in the literature highlights the unpredictable stability of this procedure. The literature review in Chapter 2 confirms that relapse may occur in the short, intermediate and long term.

The etiology of relapse is a contentious issue because consensus has not been reached regarding the individual role of various etiological factors. Chapter 3 reviews the most commonly discussed etiological factors and their perceived role in mandibular relapse.

A problem that was evident from reviewing the literature is that differences in European and North American methodology and presentation of results may confuse the issue of relapse. There is no doubt that clinical assessment of the occlusion reported in the larger European studies is a rapid means of determining relapse. However, compensatory movements in the dentition may mask skeletal relapse. Therefore in the proposed study, cephalometric investigation was selected as the most appropriate method for documenting relapse. A review of the literature relevant to cephalometry and the selection of a suitable reference line is presented in Chapter 4.

Various surgical modifications have been proposed to reduce relapse, particularly in relation to the method of fixation. This aspect has undergone several transitions and bicortical screw fixation is currently favoured. Published results suggest a promising future for this modality of fixation (Kirkpatrick et al., 1987; Van Sickels et al., 1988) but there are few well documented short or long term cephalometric studies based on homogeneously treated surgical samples.

On the basis of the literature review, several aims were established using material from the Oral and Maxillofacial Surgery unit, The University of Adelaide. The objectives of this study were to:

1. Acquire cephalometric data on patients who had bilateral sagittal split advancement of the mandible since 1985.
2. Quantify the amount of relapse in the early, intermediate and long term following surgical advancement of the mandible by bilateral sagittal split osteotomy.
3. Establish whether patient sex or age influence postsurgical relapse.
4. Establish the degree of association between previously reported etiological factors and relapse.
5. Compare the efficacy of wire osteosynthesis and screw fixation in the control of relapse.
6. Investigate the sources of error in cephalometry and quantify the error associated with the present study.
7. Quantify the error associated with selected cephalometric variables used in this study.

The investigation involved a detailed assessment of 40 serial cephalometric records. Each record was assigned to one of four groups. Group 1 consisted of bilateral sagittal split osteotomy stabilised with screw fixation. Group 2 were cases with bilateral sagittal split and Le Fort I osteotomies stabilised with screw fixation. Group 3 consisted of bilateral sagittal split osteotomy stabilised with wire fixation. Group 4 were cases with bilateral sagittal split and Le Fort I osteotomies stabilised with wire fixation. The materials and methods are detailed in Chapter 5 and the methodology for examining the error of the method is presented in Chapter 6.

The overall results are presented in Chapter 7. Student's *t*-test for unpaired values revealed that there were no statistically significant sex differences within any of the groups. In addition, no statistical differences were shown between groups 1 and 2, nor between groups 3 and 4. Therefore, the screw fixation and the wire fixation subgroups were combined and the results are presented in Chapter 8. Correlations between variables thought to be significant in relapse are presented in Chapter 9.

To validate the results of the current investigation, the error of the method was investigated and the results are presented in Chapter 10. The results showed that the experimental error was acceptably low when compared to the results from published studies.

The findings of this study are discussed in a series of chapters which parallel the results. Hence the selection of patient records is discussed in Chapter 11 and the changes which occurred during early relapse in Chapter 12. The changes which occurred during the intermediate period and long term are discussed in Chapter 13 and the error of the method is discussed in Chapter 14. The overall conclusions are presented in Chapter 15.

# II

# Review of the Literature

# CHAPTER 2

# REVIEW OF THE LITERATURE
# RELAPSE FOLLOWING BILATERAL SAGITTAL SPLIT ADVANCEMENT

### *2.1. DEFINING POSTSURGICAL RELAPSE*

Postsurgical relapse is one of the most commonly discussed complications following bilateral sagittal split osteotomy. Reichenbach (cited by Lindorf, 1986) defines relapse as "a postoperative approximation of the bite to the preoperative state." Paulus (cited by Lindorf, 1986) considers relapse to be present whenever changes in the occlusion, such as open bite, occur during the postoperative period. Whereas these definitions describe changes at the occlusal level, Reitzik (1988) interprets relapse to mean "a return to the preoperative state." This broader definition encompasses skeletal and occlusal changes and will be used in this context throughout the study.

### *2.2. MEASUREMENT OF RELAPSE*

The amount of relapse attributed to the sagittal split osteotomy varies depending upon the method of assessment. Most North American literature tends to present results as a percentage relapse of the initial mandibular advancement. European results are frequently expressed as a percentage of the patients who showed clinical or cephalometric signs of relapse.

The long term European studies (Freihofer and Petresevic, 1975; Pepersack and Chausse, 1978; MacIntosh, 1981; Lello, 1987) emphasise occlusal changes whereas North American studies (Poulton et al., 1979; Lake et al., 1981; Van Sickels et al., 1988) have placed particular importance upon cephalometric dental and skeletal changes. A criticism of the prevailing European method is that skeletal relapse may be clinically masked by compensatory movements in the dentition (Van Sickels and Flanary, 1985).

Other inconsistencies in methodology may also create misleading impressions. For example, Poulton and Ware (1973) and Huang and Ross (1982) measured mandibular changes from articulare to gnathion. This combines the horizontal and vertical losses preventing comparisons with most other papers which record horizontal relapse as a separate entity.

Several European studies (Freihofer and Petresevic, 1975; Pepersack and Chausse, 1978; MacIntosh, 1981) have examined both clinical and radiographic aspects but have not exploited cephalometrics to the same extent as the Americans. Freihofer and Petresevic's (1975) cephalometric analysis suggested that there was a change at the angle of the mandible after intermaxillary fixation release. This change was related to relapse but the rationale was not explained. MacIntosh (1981) favoured clinical assessment of relapse with occlusal casts in conjunction with cephalometric soft tissue evaluation. He graded relapse into three categories depending upon the measured changes in occlusion and soft pogonion. However, no cephalometric skeletal appraisal was mentioned. MacIntosh commented that attempts to record relapse with cast analysis became extremely difficult and were eventually abandoned.

Lake et al. (1981) used 15 cephalometric dentoskeletal variables to record long term changes. These included horizontal advancement, mandibular length, gonial arc radius, anterior and posterior height, gonial angle and incisal position. In designing his study, previously reported relapse factors—mandibular plane angle, gonial angle, facial height and condylar displacement—were taken into account. Sandor et al. (1984) based his findings of relapse on horizontal mandibular advancement, horizontal incisal tip advancement and increased mandibular length. This last measurement is not always useful because of the unreliable identification of gonion and menton (Barer et al., 1987; Vincent and West, 1987). Reitzik (1988) believes that the best parameter of measurement is the gonial angle. Comparison of the gonial angle and the mandibular plane angle will indicate how much each fragment relapses. The main problem which is apparent from reviewing the literature is that the differences in methodology often invalidate comparisons between studies and may account for differences of opinion regarding the stability of the bilateral sagittal split osteotomy.

Several authors have arbitrarily divided relapse into several phases depending upon intermaxillary fixation release. The basis for releasing fixation is derived from the physiological timing in fracture repair. Osteotomies undergo the same process of healing by secondary bone formation when non-rigid fixation is used (Spiessl, 1974).

Kraal and Valk (1981) prefer three stages of relapse: during intermaxillary fixation, at intermaxillary fixation release and long term. Sesenna and Raffaini (1985) describe 4 occasions with the potential for relapse: during intermaxillary fixation, at the moment of release, within a few months of fixation removal and at a considerable time after surgery. Recent advances in methods of internal fixation make timing in relation to intermaxillary fixation less relevant. However, several authors (Van Sickels et al. 1988) familiar with screw fixation state that the first 2 months after surgery is still a critical period for evaluation.

Other authors (McNeill et al. 1973; Ive et al. 1977; Kohn, 1978; Schendel et al. 1978; Wolford et al., 1978; Schendel and Epker, 1980; Lake et al. 1981; Will et al. 1984; Van Sickels et al. 1988) have examined relapse on a chronological basis. "Early relapse" signifies movement back towards the preoperative position within the first 2 months of surgery prior to fixation release. The "intermediate period of relapse" covers the next 4 months. Unfavourable changes which occur after 6 months are usually interpreted as "long term relapse".

Reitzik (1988) uses three periods to discuss relapse. Immediate relapse may occur upon release of intermaxillary fixation and is due to malposition of the mandibular condyles or "condylar sag" which is induced at operation. The second type of relapse is long-term relapse due to interfragmentary instability. Reitzik believes that the third type of relapse is not relapse *per se* but rather a flexural change in the shape of the mandible. This is a dynamic change which reflects the form and function of bone.

At The University of Adelaide, the chronological sequence described by Reitzik (1988) has been adopted although the term "early relapse" is preferred to "immediate relapse". The "intermediate period of relapse" has arbitrarily been defined from 2 to 12 months and "long term relapse" as any negative changes which occur thereafter. This period was chosen to avoid the superimposition of postsurgical orthodontics on relapse patterns. By twelve months, postsurgical orthodontics has usually concluded so that any morphological changes will be independent of any active treatment. Relapse percentages have been assigned a negative value throughout the text to indicate backward movement of the mandible.

### *2.3. EARLY RELAPSE*

Poulton and Ware (1971) observed that skeletal relapse was possible during intermaxillary fixation without any change in the occlusal relationship. They believed that the relapsing force arose from excessive suprahyoid muscle tension. They also noted that relapse was usually subtotal suggesting the existence of a compensatory mechanism—either a range of tolerance in resting muscle length or, migration of the bony and tendinous insertions.

McNeill and his colleagues (1973) showed that dental fixation was inadequate for controlling skeletal position. Four cases which had sagittal split advancement to correct class II deformity were presented to illustrate dental instability during intermaxillary fixation. By six weeks, the maxillary incisors had retracted whilst the mandibular incisors proclined. The authors concluded that maintenance of the occlusion with intermaxillary fixation did not prevent skeletal relapse. Relapse was thought to be related to the lengthened suprahyoid complex and possibly to the sphenomandibular ligament. Thus, detachment of these structures was suggested.

Guernsey (1974) related early relapse to the occlusal wafer and subsequently removed it within one week of surgery. He felt that the wafer obscured early detection of occlusal relapse. Guernsey confirmed that following bilateral sagittal split osteotomy, the hyoid bone moves up and forward (Wickwire, 1972) but then moved back again. He therefore supported the concept of selective suprahyoid myotomy as proposed by Steinhauser (1982).

Ive et al. (1977) studied 21 patients who had sagittal split advancement. Each patient demonstrated skeletal and compensatory dental changes during the first few weeks of intermaxillary fixation. In some cases the skeletal change continued beyond 6 weeks resulting in a compromised occlusion and profile. A mean skeletal relapse of -30% (range -11% to -71%) was measured during intermaxillary fixation and tended to increase with larger advancements. This study was amongst the first to comment on mean relapse using cephalometric material. Subsequent authors used mean values to allow comparison between studies and a selection of findings is summarised in Table 2.1.

**Table 2.1. Relapse % in the early postoperative phase.**

| Author | Year | Patients | Method | % Relapse |
|---|---|---|---|---|
| Ive et al. | 1977 | 21 | UBW | -30 |
| Kohn, | 1978 | 17 | UBW | -17 |
| Lake et al. | 1981 | 52 | UBW | -19 |
| Sandor et al. | 1984 | 20 | UBW | -10 |
| Will et al. | 1984 | 41 | UBW | -45 |
| Wade | 1988 | 12 | UBW | -19 |
| Van Sickels et al. | 1988 | 51 | Screws | -1.3 |

***Method of fixation:** UBW: Upper border wiring and intermaxillary fixation
Screws: Bicortical screw fixation

Kohn (1978) investigated relapse following mandibular advancement in 17 patients. Nine of these were advanced by bilateral sagittal split osteotomy and the remainder by C-osteotomy. Relapse of -17% occurred during fixation which Kohn blamed on proximal segment displacement. This may have been the result of inadequate condylar seating during surgery or the inability of transosseous wiring to maintain the proximal segment in the intended position.

In a well designed study, Lake et al. (1981) retrospectively studied 52 patients who had surgical advancement of the mandible. bilateral sagittal split osteotomy was performed by one surgeon who used a standardised protocol of upper border wiring, a uniformly thin occlusal wafer, 6 weeks of intermaxillary fixation and a soft cervical collar. The mean early relapse of 19% and compensatory changes in the dentition appeared during intermaxillary fixation.

Sandor et al. (1984) compared the stability of the bilateral sagittal split osteotomy with and without osteosynthesis. Forty patients were equally distributed between each group and had a similar range of mandibular advancement. The non-wire group displayed -54% relapse by the time intermaxillary fixation was released, whereas only -10% loss was seen in the upper border wire group.

Smith et al. (1985) used the lower border wiring technique in bilateral sagittal split advancement Fifty patients were monitored over the 6 week period of fixation. Relapse was assessed in three ways: (1) anteroposterior change (*x* coordinate of gnathion), (2) condylion to gnathion length changes, and (3) changes in length of the mandibular body.

Early relapse of -31% could not be explained solely by changes across the osteotomy site or proximal segment location. A significant relationship was found between the amount of advancement and the tendency for postoperative relapse. No significant relationship was shown between relapse and preoperative mandibular plane angle or posterior facial height increase.

Will et al. (1984) reported early relapse of -45% following bilateral sagittal split advancement in 41 patients. This was despite the use of cervical collars and radiographic evidence of accurate condylar position. Will and her colleagues found a significant correlation between the amount of surgical advancement and relapse, commenting that the complex area of muscle physiology may hold the key to relapse.

Ellis and Gallo (1986) reported a mean horizontal relapse of -8.9% following bilateral sagittal split osteotomy and skeletal fixation at 8 weeks postsurgery. Twenty young adults had mandibular advancement, 22 gauge circummandibular wires and 24 gauge pyriform rim wires linked with 25 gauge wires. Relapse was not correlated to the surgical advancement or to any of the other variables studied. The maxillary incisors became more upright and the mandibular incisors proclined as observed in previous studies. The authors concluded that skeletal wire fixation and intermaxillary fixation were not sufficiently rigid to prevent skeletal relapse.

More recently, however, animal studies showed that skeletal fixation can decrease relapse when compared to dental fixation alone. Mayo and Ellis (1987) advanced the mandibles of 24 *Macaca mulatta* monkeys a mean of 6 millimetres measured from tantalum markers. Six weeks after surgery the dental fixation (DF) group showed progressive horizontal relapse but none of the skeletal fixation (SF) group showed significant horizontal relapse. The amount of surgical change and observed relapse were not correlated. Statistically significant extrusion of the lower bicuspid occurred in the DF group after 4 weeks. However, this change was small (0.7 mm) and clinically the occlusion remained bonded firmly together. Mayo and Ellis thought these vertical changes resulted from suprahyoid and soft tissue tension pulling the distal segment inferoposteriorly causing extrusion of the teeth. They concluded that skeletal fixation appears warranted when intermaxillary fixation is used to stabilise the advanced mandible.

Wade (1988) studied the stability of combined Le Fort I and bilateral sagittal split advancement in 12 cases. Eight cases had additional genioplasty. Upper border wiring and dental fixation were used in all but one case which had skeletal fixation. Relapse averaged -19% by fixation release and was correlated with condylar displacement.

Only two papers reported the effects of screw fixation on early relapse. Van Sickels and Flanary (1985) treated 9 patients with bilateral sagittal split advancement stabilised with bicortical screws as described by Jeter (1984). Three patients had concurrent reduction genioplasties. Minimal horizontal relapse (0.1-0.4 mm) occurred in the first 6 weeks at B point signifying a promising trend with screw fixation. More recently, Van Sickels et al. (1988) showed that screw fixation provided good short term surgical stability in 51 patients. Insignificant relapse of -1.3% occurred in the first 6 weeks. In contradistinction to the dental changes seen with intermaxillary fixation, the upper incisors flared and the lower incisors retracted.

### *2.4. INTERMEDIATE AND LONG TERM RELAPSE*

Poulton and Ware (1971) reported encouraging 6 month results in one patient with severe mandibular hypoplasia and apertognathia. They attributed the relatively low (-23.1%) relapse to protracted use of the Milwaukee chin brace. In two other patients with less dentofacial deformity who did not use the brace, relapse averaged -43.7% at six months.

Poulton and Ware (1973) found that 8 patients with mandibular hypoplasia and apertognathia relapsed -10 to -30% in the medium to long term (9-43 months). This significant reduction in relapse compared to their earlier figures (1971) appeared to be strongly correlated to the patient's compliance with the chin brace. Poulton and Ware believed the brace helped to "increase permanently the length of the muscles relating the chin to the neck."

Poulton et al. (1979) performed a long term study involved 20 patients of which 7 were 38 months postsurgery. This study used cases from their previously published material. Cephalometric superimposition showed that horizontal and vertical alterations at the lower incisal tip and pogonion occurred during fixation and up to 42 months later but at a rapidly declining rate. Change after 17 months averaged 1 mm. Six patients with the least horizontal relapse and six cases with the most horizontal relapse were compared. All of the non-relapse group had received postoperative neck braces. Only one of the high relapse group received this chin support postoperatively. Poulton et al. claimed that use of the neck brace for at least 6 months helped to maintain surgical advancement.

Freihofer and Petresevic's (1975) article on bilateral sagittal split osteotomy was one of the first with a large data pool from which valid conclusions on occlusal relapse could be drawn. Of 118 cases with mandibular hypoplasia 38 had been followed for at least 2 years with a mean of 5 years. Relapse was evaluated by occlusal cast and brief cephalometric analyses. In contrast to previous papers, the authors reported that in their series the occlusal relationship was a good indicator of skeletal stability.

Casts were measured with a 1 mm range for measurement error. Twenty-six (69%) of the patients showed no relapse. Relapse of -10% to -60% was seen in 11 cases and was related to poor occlusal interdigitation or condylar malposition. It was pointed out that where the advancement was small a change in overjet of 2 mm would give a high percentage of relapse despite a good clinical result. Total relapse occurred in one patient without a clear cause. Nine of the patients had a posterior open bite although the last molar was in occlusal contact. No comment was made as to whether this lack of interdigitation may have contributed to relapse.

In cases which underwent skeletal relapse, anterior tooth movement and loss of posterior facial height were evident. Freihofer and Petresevic stated that condylar distraction was a recognised cause of relapse but there was no correlation with the experience of the surgeon, the amount of advancement, or the age of the patient. The authors found that in the majority of cases, relapse was limited once a good occlusion had been established.

Kohn (1978) found that -17% relapse occurred during fixation whilst a further -32% was reported after 6 months or more. No significant relationship was found between preoperative mandibular plane angle and skeletal relapse even though almost half of the sample were reported to have high mandibular plane angles. No significant difference in relapse tendency could be found between patients who had preoperative orthodontics and those that went directly to surgery. Kohn concluded that relapse was most highly correlated with proximal segment displacement.

Isaacson et al. (1978) tried to avoid the problem of condylar displacement or "condylar sag" by dispensing with skeletal fixation. He reasoned that the proximal segment would reach "biological equilibrium" and thus minimise the effect of condylar displacement on relapse. His results, based on only 3 patients, did not appear to support his concept as an average 3.7 mm (-43%) relapse was recorded at 9 to 12 months postsurgery.

Brammer et al. (1980) examined the data of 12 Caucasian females who underwent bimaxillary surgery to correct vertical maxillary excess and absolute mandibular deficiency. The average mandibular plane angle was

50.8° (range: 38.4° - 59.7°) and six patients had anterior open bite. After an average followup 8 months later, they found a strong correlation between posterior maxillary impaction and decreased mandibular relapse. Soft cervical collars and suprahyoid myotomies did not correlate well with mandibular stability, however, the group was small and heterogeneously treated.

In the study by Lake et al. (1981), an average net relapse of -25% was measured in the long term (mean: 3.5 years). There was a tendency for larger advancements to relapse further in absolute terms but the percentage relapse was unpredictable. No significant relationship was found between age and relapse.

Kraal and Valk (1981) commented that increased posterior and anterior facial height may be associated with long term relapse. However, good occlusal stability would maximise long term control.

MacIntosh (1981) reviewed the results of 155 patients treated with bilateral sagittal split osteotomy to correct prognathia (55.8%), retrognathia (38.5%) and apertognathia (5.8%). Seventy-three per cent of cases had additional dentoskeletal deformities. MacIntosh considered that paraesthesia and relapse constituted the major postoperative problems. Half the patients with retrognathia and apertognathia relapsed more than 3 mm at the occlusal level.

MacIntosh found that 11.2% of patients had occlusal changes greater than 1 mm but only 2.5% had equivalent cephalometric change. He considered that his results showed relapse similar to Pepersack and Chausse (1978) but less than Freihofer and Petresevic (1975).

Relapse was reported by Martis (1984) as one of the complications following bilateral sagittal split osteotomy. intermaxillary fixation was maintained for 11 weeks but no osteosynthesis wires were used except in cases of severe retrognathia. He observed 5 of 36 (13.8%) of patients treated for retrognathia had relapse of more than 1 mm at the occlusal level.

Sandor et al. (1984) was unable to recommend non-skeletal fixation for bilateral sagittal split osteotomy (Isaacson et al., 1978) on the basis of his short and medium term results. The non-wire group (N = 20) displayed most relapse ( $\bar{x}$ = -77%) after one year and 6 patients relapsed completely. Condylar distraction was blamed for some of the relapse. These results compared with a mean relapse of -23% for patients who received osteosynthesis (N = 20) as described by Epker (1977). No increase in the gonial arc radius or posterior facial height was noted.

Lello (1987) reported on a small series (N = 10) of skeletal open bite cases treated by Le Fort I and bilateral sagittal split osteotomy. Wire osteosynthesis was used in all cases and after an average followup of 6.5 years, only 3 cases had clinically significant relapse. All relapse had occurred by 1 year. No correlation was noted between the mandibular plane angle and relapse.

Wade (1988) studied long term stability following combined Le Fort I and bilateral sagittal split advancement secured by wire osteosynthesis. All 12 cases underwent early relapse (-19%) but had minimal relapse (0.9 mm or 1%) at 6 months review. After 2 years a total mean relapse of -27% had occurred and "appeared to be a physiologic muscular adaptation following the influence of surgery, orthodontic appliances, elastics, retainers and some continued nasorespiratory difficulty."

There has been an increasing number of studies which associate screw fixation and improved skeletal stability compared to wire fixation (Table 2.2). Van Sickels and Flanary (1985) treated 9 patients by bilateral sagittal split advancement and rigid fixation (Jeter et al., 1984). Three patients had concurrent reduction genioplasties. At the 6 month review a slight forward movement (1.0-1.4 mm) had occurred at B point highlighting the apparent stability of screw fixation.

Van Sickels and his colleagues (1986) reviewed 19 patients who had rigid fixation. Ten patients had bilateral sagittal split osteotomy only, 5 had genioplasty setback and 4 had advancement genioplasty. They found that after 6 months, mandibular relapse was minimal unless the advancement exceeded 6 mm at pogonion. In these individual cases, relapse of -30 to -50% was seen.

**Table 2.2: Relapse % in the intermediate and long term.**

| Author | Year | Patients | Method | Period (mo.) | % Relapse |
|---|---|---|---|---|---|
| Poulton & Ware | 1971 | 3 | UBW | 6 | -23 - -44 |
| Poulton & Ware | 1973 | 8 | UBW | 9-43 | -10 - -30 |
| Freihofer & Petresevic | 1975 | 118 | UBW | 24-60 | -10 - -60 |
| Kohn | 1978 | 17 | UBW | 6-24 | -49 |
| Isaacson et al. | 1978 | 3 | IMF only | 9-12 | -43 |
| Lake et al. | 1981 | 52 | UBW | 42 | -25 |
| Sandor et al. | 1984 | 20 | UBW | 12 | -23 |
| Wade | 1988 | 12 | UBW | 24 | -27 |
| Van Sickels et al. | 1986 | 19 | Screws | 6 | < -5 |
| Kirkpatrick et al. | 1987 | 20 | Screws | 6 | -8 |
| Van Sickels et al. | 1988 | 51 | Screws | 6 | < -5 |

***Method of fixation:** UBW: Upper border wiring and intermaxillary fixation (IMF)
Screws: Bicortical screw fixation

Lindorf (1986) attributed postsurgical stability to accurate orthodontic treatment and triple tandem screw fixation. He agreed with Voy (1981) that good occlusion is the best prophylaxis against relapse. At 12 months followup, occlusal relapse was observed in 3 (7%) of his 43 cases.

The results of Kirkpatrick et al., (1987) showed that bicortical screw fixation conferred good surgical stability. Postsurgical followup of 20 patients after six months showed a mean relapse of -8% (0.42 mm) at B point and a mean increase of 0.2 mm in lower facial height. Both changes were statistically insignificant. No relationship with age, sex, mandibular plane angle or magnitude of advancement was found to influence the stability of the surgical result.

Van Sickels et al. (1988) verified that screw fixation provided good surgical stability in 51 patients. After a minimum 6 months, analysis showed that no statistically or clinically significant change had occurred at pogonion.

Raveh et al. (1988) reported on a series of 103 patients treated with bilateral sagittal split osteotomy and bicortical screw fixation. Twenty of these were isolated mandibular advancements and another 14 were bimaxillary. Relapse was only briefly mentioned. Eleven of the 103 cases had some occlusal instability and three had skeletal changes of 2 to 3 mm. One of these developed an anterior open bite within 5 months which was attributed to insufficient tightening of the screws and inadequate suprahyoid myotomy.

### 2.5. *SUMMARY*

The volume of literature devoted to the bilateral sagittal split osteotomy and relapse is extensive. The literature review indicated that despite refinements in technique and an improved understanding of the biological mechanisms involved, some postsurgical relapse appears inevitable.

Three considerations related to the study and presentation of relapse results were evident from the literature review. European studies tend to confine their assessments to the occlusal level whereas North American reports favour cephalometric dentoskeletal studies. Secondly, European reports measure relapse rate by the number of patients who have had unfavourable occlusal changes. The North Americans use backward movement at the anterior aspect of the mandible to measure relapse as a percentage of the original advancement. Finally, the definition of short and long term differs between studies. The Americans consider 6 months or more as long term whereas European studies such as Pepersack and Chausse (1978) define 5 years or more as long term.

From the North American literature, relapse rates based on cephalometric studies vary between -11% to -71% (Ive et al., 1977) in the short term and -25% (Lake et al., 1981) to -80% (Poulton and Ware, 1973) in the long term. By comparison, long term occlusal relapse has been reported in 33% of patients surveyed by Freihofer and Petresevic (1975).

The dramatic relapse figures frequently quoted in the literature are based upon small studies or on an uncharacteristic individual case. Thus in the study by Ive et al. (1977), relapse of -30% more accurately reflects the mean change during fixation. Inconsistencies in methodology may also create misleading impressions. For example, Poulton and Ware (1973) and Huang and Ross (1982) measured mandibular changes from articulare to gnathion. This combines the horizontal and vertical losses preventing comparisons with most other papers which record horizontal relapse as a separate entity. Furthermore, the highest relapse rates are associated with class II apertognathic cases which MacIntosh (1981) believes are inappropriate candidates for bilateral sagittal split osteotomy.

There is no doubt that clinical assessment of the occlusion reported in the larger European studies is a rapid means of determining relapse. However, Van Sickels and Flanary (1985) has pointed out that compensatory movements in the dentition may mask skeletal relapse. Measurements made at the occlusal level ignore the rotational effects of mandibular advancement. This has particular significance in anticlockwise rotations since the mandible may be advanced a measurable distance with little change at the occlusal level. The problem is compounded by the fact that anticlockwise advancements are subject to high relapse potential (Epker et al., 1978). Therefore, small occlusal movements are not only prone to higher percentage relapses if relapse occurs (Freihofer and Petresevic, 1975), but may also be relapsing considerably at the skeletal level without much change in occlusion.

Whilst the occlusion remains an important clinical entity, it would appear to be a less reliable means of assessing surgical stability. Changes at the skeletal level cannot be evaluated readily particularly when postsurgical dental compensations occur. Therefore, documentation of dentoskeletal relapse using cephalometric records potentially provides more detailed information.

# CHAPTER 3

# FACTORS ASSOCIATED WITH POSTSURGICAL RELAPSE FOLLOWING BILATERAL SAGITTAL SPLIT ADVANCEMENT

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## *3.1. INTRODUCTION*

A multiplicity of factors is commonly held responsible for postsurgical relapse. The individual contribution of each remains uncertain since the causal mechanisms have not been fully clarified. Furthermore, it is highly probable that other unrecognised causes currently exist. Whilst this situation remains, relapse may not be entirely eliminated until the etiology is completely determined. Epker et al., (1978), Worms et al., (1980) and Stoelinga and Leenen (1981a) listed the most frequently implicated factors and each will be reviewed under the following headings:

1. orthodontics
2. magnitude of advancement
3. condylar position
4. rotational effects
5. method of fixation
6. muscular interaction
7. viability of osseous segments
8. growth of skeletal structures

### 3.2. *ORTHODONTICS*

The combined orthodontic and surgical approach in the management of skeletal mandibular hypoplasia has gained widespread acceptance. The reduction in total treatment time and potential for improved occlusal stability, dentofacial function and aesthetics represent distinct advantages over isolated orthodontic treatment (Kraal and Valk, 1981; Lake et al., 1981; Stoelinga and Leenen, 1981a; West and McNeill, 1981). Orthodontic treatment is routinely used in presurgical preparation of the dental arches to relieve dental compensations and overcrowding. Where anterior facial height is acceptable, the occlusal plane is levelled presurgically (Bell and Jacobs, 1979). On the other hand, cases demonstrating decreased lower facial height are easier to level postoperatively (Stoelinga and Leenen, 1981a, 1981b).

These measures are devoted towards maximal intercuspation and generation of a postsurgical class I canine relationship to prevent relapse. Lindorf (1986) agrees that good orthodontic alignment in the preoperative and postoperative phase is the best prophylaxis against relapse. Freihofer and Petresevic (1975) also believe that relapse is limited once good intercuspation is established. Zetz and his associates (1984) described a method which achieved early postsurgical interdigitation whilst the patient was still in intermaxillary fixation. They temporarily removed fixation, shortened the occlusal wafer to the canines, reapplied intermaxillary fixation and recommenced elastic traction. Extrusion took no longer than 6 weeks. According to Zetz et al., the advantages of this method were that orthodontics commenced whilst the patient was still in intermaxillary fixation thus shortening the total treatment time. Secondly, arch levelling was easier since the teeth erupted into posterior spaces created by jaw advancement.

On occasion, orthodontics may contribute to relapse. The risk of relapse is increased if orthodontic treatment tries to achieve a functional occlusion prior to surgery. Consequently, teeth are placed in an unstable position relative to their alveolar foundation, ignoring the underlying skeletal dysplasia (West and McNeill, 1981). Orthodontics may cause increased tooth mobility through rapid tooth movement which compromises the periodontium and may reduce root surface. Epker et al. (1978) recommended skeletal rather than dental fixation when this problem was present. Kohn (1978) however, treated 9 of 17 patients with presurgical orthodontics and was unable to show a significant correlation between postoperative relapse and presurgical orthodontics.

### *3.3. MAGNITUDE OF ADVANCEMENT*

The magnitude of advancement as a relapse factor may reflect the increasing resistance of the stretched soft tissues. Many authors ( Epker et al., 1978; Brammer et al., 1980; Lake et al., 1981; Will et al., 1984; Van Sickels et al. 1986; Barer et al., 1987; Van Sickels et al., 1988; Wade, 1988) agree that the larger the skeletal advancement, the greater the potential for relapse. Epker et al. (1978) preferred measurement of skeletal landmarks, as opposed to occlusal measurement, so that rotational effects during mandibular advancement were taken into account. They stated that anticlockwise rotation maximised the relapse potential and strongly advised the use of an overcorrected occlusal splint, both vertically and anteroposteriorly. Worms et al. (1980) similarly commented that anticlockwise advancements were unstable and conjectured that an inviolate functional matrix exists. The more this matrix was distorted and compressed, the greater the risk of relapse.

Egyedi (1980) dealt with potential relapse by overcorrecting the severely mandibular deficient patient. The mandible was advanced into a cephalometrically overcorrected position and into a class III occlusion which assisted stability. The need for further maxillary osteotomy, postsurgical orthodontics and prosthetic rehabilitation could be assessed after mandibular healing.

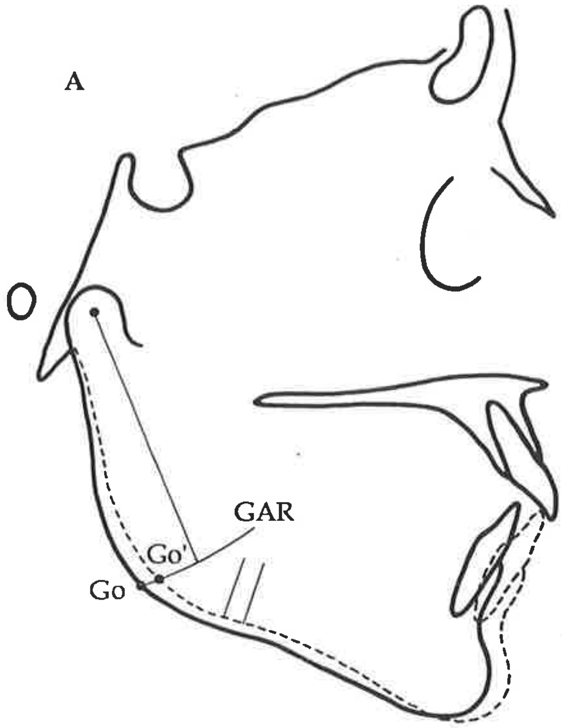
Stoelinga and Leenen (1981a) also accepted that overcorrection was warranted where relapse is anticipated. They routinely used occlusal splints which provided an edge-to-edge incisal position and posterior bite opening as advocated by Epker et al., (1978). Stoelinga and Leenen felt that prolonged periods of intermaxillary fixation, particularly with an overcorrected splint, would improve surgical stability. They recommended that intermaxillary fixation should be preserved until skeletal stability was confirmed radiographically.

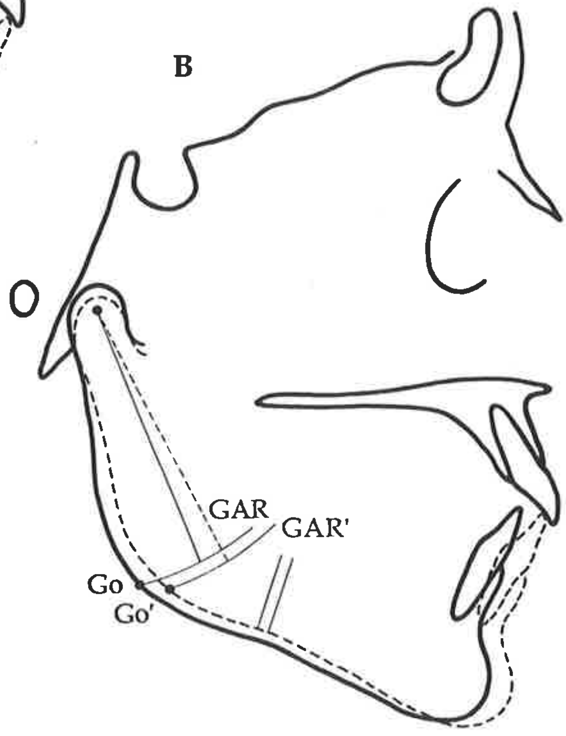
### *3.4. CONDYLAR POSITION*

Improper condylar position is considered by many to be a major factor in relapse. Several studies imply that condylar displacement causes skeletal relapse because of a discrepancy between apparent centric relation at surgery and true centric relation (Isaacson et al., 1978; Kohn, 1978; Schendel et al., 1978; MacIntosh, 1981; Schendel and Epker, 1980; Lake et al., 1981; Epker and Wessberg, 1982; Sandor et al., 1984, Hase, 1988). Kohn (1978) introduced the gonial arc radius to cephalometrically assess condylar displacement (Figure 3.1). Its usefulness was later verified by Lake et al. (1981).

Meticulous manual manipulation of the proximal segment posterosuperiorly may not guarantee accurate location because of the possible effects of muscle relaxant, intracapsular oedema (Wade, 1988) and tissue tension (Will et al., 1984). Condylar locating devices have been recommended (Leonard, 1976; Zecha et al., 1978; Leonard, 1985; Luhr, 1985; Raveh et al., 1988) but have not found universal acceptance.

Lake et al. (1981) considered that the most likely causes of early relapse are failure to seat the condyle at the time of surgery or gradual condylar displacement due to the soft tissue pull. This latter concept was supported by Wessberg et al. (1982) who found that the paramandibular connective tissues, especially the periosteal attachment, were implicated in relapse. If the condylar-ascending ramus is not properly located or orientated within the fossa, the pterygomasseteric sling may not counteract the relapsing potential of the paramandibular soft tissues. Even if the condyle is properly seated some skeletal relapse will occur during intermaxillary fixation depending on the orientation of the proximal segment, the paramandibular soft tissue tension, the mobility of the teeth and the magnitude of advancement.




**A** No change in gonial arc radius has occurred following surgery (-----) although there has been anterosuperior movement of the proximal segment.

**B** Gonial arc radius has lengthened following mandibular surgery (-----) representing condylar displacement. (Adapted from Lake et al., 1981)

**Figure 3.1 : Superimposed tracings showing the use of gonial arc radius (HA-Go)**

Will et al. (1984) challenged the role of condylar relation in relapse claiming that a mean -37% net relapse was seen in their study despite accurate repositioning of the condyle. This suggests that condylar position may be overemphasised and underscores the multifactorial nature of postsurgical instability. Smith and his colleagues (1985) reported condylar return postsurgically but they remarked that neither changes across the osteotomy site or proximal segment location could account solely for their observed relapse of -31%.

### *3.5. ROTATIONAL EFFECTS*

Relapse has been associated with increased posterior facial height, decreased anterior facial height, and altered mandibular plane angle induced by mandibular advancement. These parameters change when interfragmentary rotation occurs between the proximal and distal segments. Attempts to close anterior open bite with bilateral sagittal split osteotomy alone, is liable to relapse since increased posterior vertical dimension stretches the pterygomasseteric sling and paramandibular tissues (Wolford et al., 1978; Schendel and Epker, 1980).

Kohn (1978) believed that a predictive relapsing effect existed if posterior facial height increased more than 3 mm at surgery. Anticlockwise rotations decrease anterior facial height and mandibular plane angle putting the suprahyoid complex under tension. Epker et al. (1978) remarked that the combined soft tissue forces have a natural tendency to distract the condyle from the fossa adding to relapse tendency.

Lake et al. (1981) found that increased posterior facial height at surgery was associated with short-term relapse. When patients were subdivided by changes in posterior facial height, fifty percent (26) of the cases had a mean increase of 2.1 mm (35%) compared to the remaining 26 cases who averaged 1.1 mm (17%). Although both groups were advanced a similar amount, the first group relapsed more by the time fixation was released. Relapse of this nature appeared to be secondary to positional changes of the condylar segment. Lake et al. noted that the increase in posterior facial height occurred randomly at surgery.

Greebe and Tuinzing (1984) were able to relate skeletal stability to the preoperative facial height ratio. Posterior facial height (PFH) was defined as the distance from sella to gonion and anterior facial height (AFH) as the distance from nasion to pogonion. Twenty-four patients had mandibular advancement, intermaxillary fixation for 6 weeks and no skeletal fixation. They found that good stability could be anticipated if the PFH/AFH ratio was above 72%. A PFH/AFH ratio below 66% was found to predispose to instability and warrants additional measures to prevent relapse. Between these values, the authors contended that any relapse tendency could be masked by orthodontics. Although the ratio appears to be useful, it merely re-expresses preoperative mandibular plane angle in a different way.

### *3.6. METHOD OF FIXATION*

McNeill and co-workers (1973) carried out a retrospective cephalometric evaluation of skeletal and dental relationships during intermaxillary fixation which indicated that dental structures were not stable and concluded that some form of osseous fixation was necessary to minimise skeletal relapse. It is clear that stability has been enhanced by the evolution of fixation methods over the past decade. Circummandibular wiring at the osteotomy site as proposed by Trauner and Obwegeser (1955) has largely been superseded by upper border wiring (Obwegeser, 1957; Epker, 1977; Epker and Wolford, 1980) and multiple screw fixation (Spiessl and Tschopp, 1974; Spiessl, 1976; Paulus and Steinhauser, 1982; Jeter et al., 1984). Combined dentoskeletal fixation (Ellis and Gallo, 1986) and lower border wiring (Booth, 1981) are two other methods which reportedly control relapse. Considerable attention has consequently been focused upon the methods of osteosynthesis (Figures 3.2-3.10) during healing of the osteotomy site with particular emphasis on control of the proximal segment (Table 3.1).

**Table 3.1: METHODS OF OSTEOSYNTHESIS**

| | |
|---|---|
| 1. Intermaxillary fixation only | : Isaacson et al. (1978)<br>: Nickerson (1983) |
| 2. Circumferential wiring* | : Obwegeser (1955)<br>: MacIntosh (1981)<br>: Ellis & Gallo (1986) |
| 3. Upper border wiring* | : Obwegeser (1957)<br>: Epker 2 hole (1977)<br>: Epker 3 hole (1980) |
| 4. Lower border wiring* | : Booth (1981) |
| 5. Skeletal fixation* | : Epker et al., (1978) |
| 6. Compression techniques: | |
| screws | : Spiessl (1974) |
| 7. Non-compression techniques: | |
| K-wires* | : Spiessl (1974) |
| screws | : Jeter et al. (1984) |

* In conjunction with intermaxillary fixation.

### *3.6.1. Intermaxillary fixation without skeletal osteosynthesis (Figure 3.2)*

Isaacson et al. (1978) argued that in the absence of interosseous fixation the proximal and distal fragments were free to seek "biologic equilibrium". He further reasoned that incorrect alignment of the osteosynthesis holes would cause distraction of the condylar fragment when the wire was tightened. Sandor et al. (1984) agreed that poorly placed interosseous fixation was an obvious cause of condylar distraction. Isaacson et al. subsequently reported short-term success based upon occlusal results for six patients who were operated upon without osteosynthesis.

Subsequent studies by Stoelinga and Leenen (1981a) and Sandor et al. (1984) showed that Isaacson et al.'s hypothesis was unsupported. Sandor and his coworkers recorded a mean relapse of -77% as late as two years post-operatively, associated with condylar distraction in the non-osteosynthesis group. The conclusion of Sandor's study was that omission of interosseous fixation during mandibular advancement could not be recommended because of the tendency towards condylar distraction, increased risk of unacceptable flattening of the mandibular angle (due to anti-clockwise rotation of the proximal segment) and the high incidence of relapse.

Nickerson (1983) used a novel approach to prevent anterosuperior rotation of the ascending ramus whilst still allowing "biological equilibrium" of the proximal segment. He modified a Champy miniplate into a forked extension. The upper fork was bent to engage the superior border of the proximal segment. The design allowed limited anteroposterior movement but prevented lateral displacement of the proximal fragment. Of 16 osteotomy sites, 2 had inadequately seated condyles. These corrected when the patient performed jaw clenching exercises.

Prolonged intermaxillary fixation (11-12 weeks) has been recommended by McNeill et al. (1973) and Martis (1984). Martis believes that this is more important than any kind of osteosynthesis during the period of bony union and neuromuscular adaptation. Unfortunately he based his low relapse rates on occlusal change and did not quantify the incidence of skeletal relapse in his sample.

## METHODS OF FIXATION

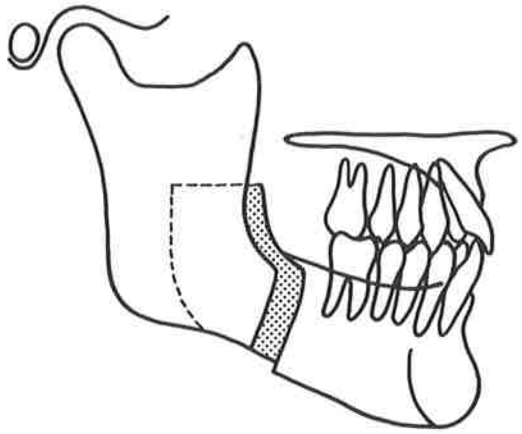


Figure 3.2 : **Intermaxillary fixation only and no osteosynthesis**

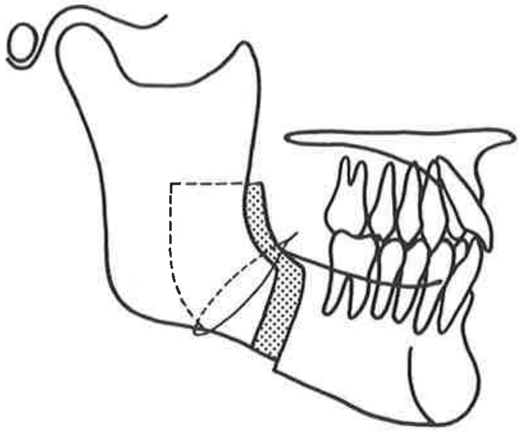


Figure 3.3 : **Intermaxillary fixation with circumferential wire osteosynthesis**

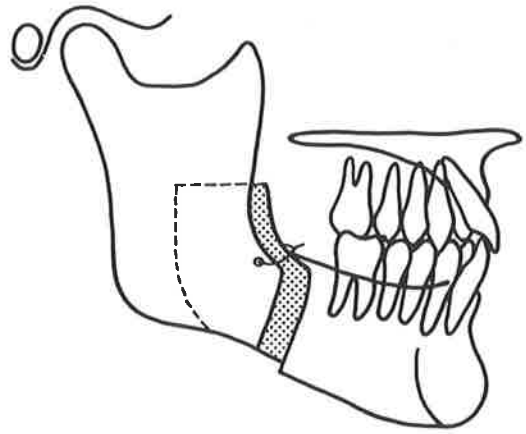


Figure 3.4 : **Intermaxillary fixation with upper border wire osteosynthesis**

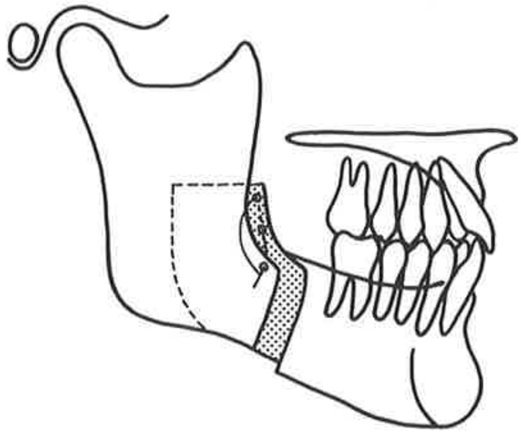


Figure 3.5 : **Intermaxillary fixation with Epker's "high-low" modification (1980)**

## METHODS OF FIXATION

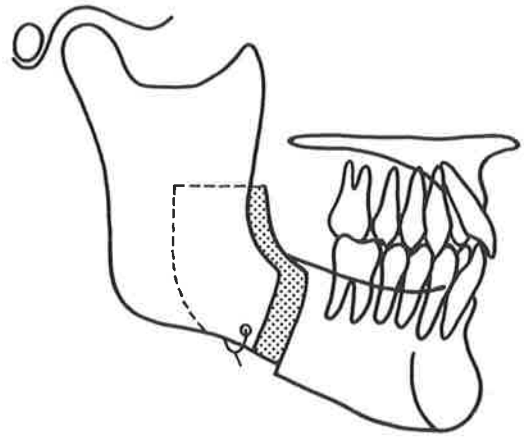


Figure 3.6 : Intermaxillary fixation with lower border wire osteosynthesis

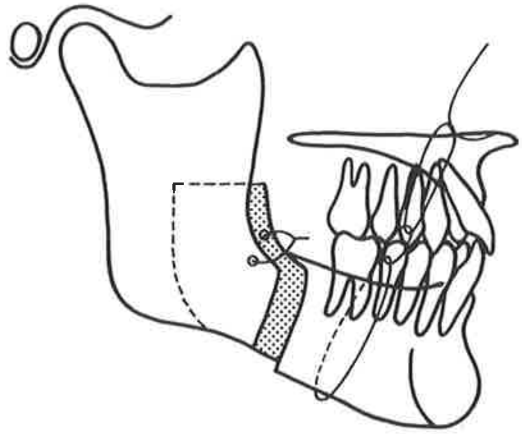


Figure 3.7: Intermaxillary fixation with circummandibular and piriform aperture wiring

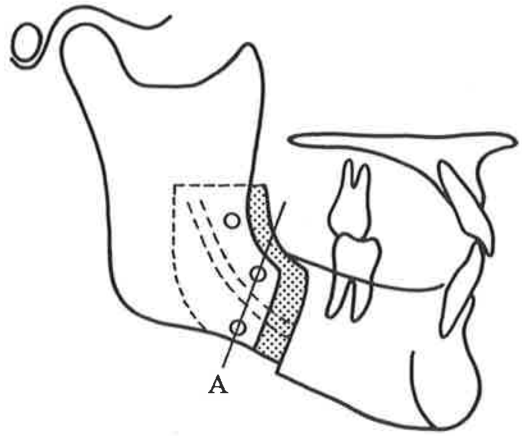



Figure 3.8 : Typical location of screws for tripod screw fixation

Cross-section of Figure 3.8 at A


Figure 3.9 : Compression lag screws
No gap between the two segments
Threads of screws only engage medial segment

Figure 3.10 : Non-compression bicortical screws
Note gap between the two segments
Threads of screws engage proximal and distal segments

### 3.6.2. *Circumferential wiring (Figure 3.3)*

The use of circumferential wiring was proposed in the original description for sagittal splitting of the mandible (Trauner and Obwegeser, 1955). More recently it has been used in conjunction with pyriform aperture wiring and intermaxillary fixation (Epker and Wessberg, 1982; Ellis and Gallo, 1986).

MacIntosh (1981) believes that the circumferential wire has several advantages over the upper border wire. Correctly placed circumferential wires provide good bony adaptation but allow enough movement for physiological seating of the condylar head. He argued that the upper border wire could forcefully distract the condyle, create a lateral divergence at the lower border and may be difficult to place in cases of prognathism.

### 3.6.3. *Upper border wiring (Figures 3.4 & 3.5)*

The popularity of the upper border wire is legion and until recently, was invariably described as part of the operative procedure. The technique of upper border wiring was introduced by Obwegeser (1957) and useful modifications were offered by Epker in 1977 and 1980. Epker and Wolford's later modification (1980) of the "high-low" technique introduced in 1977 was designed to posterosuperiorly reposition the condylar segment into the fossa. No long term studies are available to confirm the efficacy of this modification.

Long term studies which have relied on the conventional upper border wire report a relapse ranging from -23% (Sandor et al., 1984) to -80% (Poulton and Ware, 1973). The study by Lake et al. (1981) of 52 patients treated with upper border wiring is a useful standard against which other techniques can be judged. They recorded a mean relapse of -26% after 42 months with most of the relapse (-19%) occurring in the first 8 weeks.

The earlier cases of Poulton and Ware were only a few in number and had combined mandibular apertognathia and hypoplasia complicating the issue of relapse. Obwegeser (1964) emphasised that bilateral sagittal split osteotomy would be subject to relapse if the cause of the dentofacial deformity was not corrected. He cited the activity and size of the tongue as relapse factors in apertognathia and recommended tongue reduction. MacIntosh (1981) considered that bilateral sagittal split osteotomy alone was contraindicated in the treatment of apertognathic cases.

### 3.6.4. *Lower border wiring (Figure 3.6)*

Despite wiring of the split segments at the upper border to negate displacement of the proximal segment, Booth (1981) has expressed concern that anterosuperior displacement is still a frequent occurrence. He observed during tightening of the wire that the proximal segment distracted until both superior borders were level. This rotation of the proximal segment could contribute to relapse if the condyle was concomitantly distracted and also produce a less acceptable gonial angle (Singer and Bays, 1985). By using a lower border approach, tightening of the wire brings both inferior borders together, thus preserving the preoperative position of the proximal segment.

Singer and Bays (1985) compared the upper and lower border osteosynthesis techniques and found that wiring at the lower border caused significantly less anterosuperior rotation of the proximal segment and less loss of the gonial angle. Smith et al. (1985) performed a similar investigation and arrived at the same conclusion. They found that although there was statistically significant movement of the proximal segment, this small change was not apparent clinically. Their observations regarding relapse, however, showed that there was no improvement with lower border wiring. Smith and his associates measured -31% relapse during intermaxillary fixation which was similar to the -30% reported by Ive et al. (1977) for upper border wiring.

### 3.6.5. *Skeletal fixation (Figure 3.7)*

The virtues of skeletal fixation were first discussed by Epker et al. in 1978. They felt that relapse could be curbed by bypassing the periodontium thereby avoiding the problem of dental extrusion. "The use of bilateral circummandibular wires over the occlusal splint and pyriform rim, infraorbital rim or circumzygomatic wires to the splint....provide excellent skeletal stability by securing the lower jaw to the upper jaw by means other than wiring of the teeth together." Epker and Wessberg (1982) stated that skeletal stabilisation with a class II vector could prevent skeletal relapse and associated dental compensations.

Twenty patients with intermaxillary fixation and skeletal fixation were evaluated by Ellis and Gallo (1986) following mandibular advancement. Twenty-two gauge circummandibular wires and 24 gauge pyriform rim wires were linked with a 25 gauge wire. Comparison of the preoperative and 8 week postoperative film showed that -8.9% horizontal relapse occurred. The authors concluded that "the use of skeletal wire fixation was found to supplement the dental fixation however, the skeletal wires were not sufficiently rigid to prevent skeletal relapse."

From their observations of 24 *Macaca mulatta* monkeys with intermaxillary fixation and adjunctive skeletal fixation, Mayo and Ellis (1987) found that skeletal fixation was more stable than dental fixation alone. Surgery consisted of insertion of tantalum bone markers followed by bilateral sagittal split advancement of 6 mm with upper border wiring. Cephalograms were compared up until six weeks after surgery. The dental fixation (DF) group showed progressive horizontal relapse during the period of observation whereas none of the skeletal fixation (SF) group showed significant horizontal relapse.

### 3.6.6. *Compression (lag) screws (Figure 3.8 & 3.9)*

The use of bone screws was popularised by Spiessl (1974), Schmoker et al. (1976) and Souyris (1978). Others have reported favourable results following bilateral sagittal split osteotomy setback and lag screw fixation (Schilli et al., 1981, Paulus and Steinhauser, 1982). Numerous advantages and disadvantages over conventional forms of fixation have been reported and are listed in Table 3.2.

**Table 3.2: ADVANTAGES AND DISADVANTAGES OF LAG SCREW FIXATION**

| ADVANTAGES | DISADVANTAGES |
|---|---|
| 1. Primary bone healing<br>2. Ability to check passive condylar function<br>3. Ability to reintubate the patient orally and perform nasal or midface procedures<br>4. Early functional restoration (early intermaxillary fixation release)<br>5. Decreased risk of infection if stable<br>6. Easy patient care, oral hygiene and nutrition<br>7. No lateral prominence | 1. Risk of greater displacement of the condyle<br>2. Injury to the inferior alveolar nerve either by compression or inadvertent perforation by a bone screw<br>3. Possible damage or irritation by protruding tips of screws<br>4. Palpable screwheads and plates<br>5. Reoperation for removal of the screws or plates |

Surprisingly there have been no detailed cephalometric studies which report on the long term stability of bilateral sagittal split advancement with lag screw fixation. However, a number of studies are available which comment on the use of lag screws in bilateral sagittal split osteotomy setback. In an account of 75 cases of mandibular hyperplasia, Spiessl (1974) claimed occlusal relapse was absent when 3 screws per side were used. This compared with relapse in 12.5% of patients with 2 screws, 15% with one screw and 50% with wire or K-wire osteosynthesis. Paulus and Steinhauser (1982) treated 83 patients with mandibular prognathism and found that there was less relapse with screw fixation compared to wire osteosynthesis.

When bone screws were used, occlusal relapse (> 1 mm) in 7% of patients was observed compared to 17.5% of patients with wire osteosynthesis.

### 3.6.7. *Non-compression screw fixation (Figure 3.10)*

In view of the theoretical effects of compression techniques on the inferior alveolar nerve and temporomandibular joint orientation, Jeter et al. (1984) proposed non-compressive bicortical screw fixation. Van Sickels et al. (1986; 1988) reported minimal long term relapse with this form of fixation. They found that pogonion moved forward in the long term suggestive of a skeletally immature population. However, advancements which exceeded 7 mm tended to relapse considerably (-14 to -33%) in the first six weeks. It was therefore concluded that rigid fixation cannot counteract relapsing forces beyond a certain limit.

Lindorf (1986) reported encouraging results following the use of triple tandem bicortical screw fixation to secure the bilateral sagittal split osteotomy. Occlusal relapse was observed in 7% of 43 cases he reviewed after a minimum of 12 months. Kirkpatrick et al., (1987) published his results following bilateral sagittal split advancement and bicortical screw fixation. Postsurgical followup of 20 patients after six months showed a statistically insignificant mean relapse of -8% (0.42 mm) at B point.

Published results suggest a promising future for this modality of fixation. The reduction in relapse appears to be preserved into the long term but there are few well documented cephalometric studies based on large homogeneous surgical samples.

### 3.7. *MUSCULAR INTERACTIONS*

The contribution of suprahyoid and masticatory muscular interaction in surgical relapse has been acknowledged. Disruption to the existing musculoskeletal equilibrium following osteotomy is the most commonly postulated mechanism (Poulton and Ware, 1971; Farrell and Kent, 1972; Wickwire et al., 1972; Steinhauser, 1973; Guernsey, 1974; Epker et al., 1978; Arvystas, 1979; Finn et al., 1980; Sandor et al., 1984). It is widely accepted that attempts to increase resting muscle length will encourage relapse (Yellich et al., 1981).

Arvystas (1979) believed that the influence of the suprahyoid musculature could be explained in terms of mechanical advantage. These muscles, being situated further from the joint axis, have a long lever arm capable of exerting considerable force at the joint. He therefore concluded that stable results could only be achieved if tensile forces on the suprahyoid muscles were minimal.

To counteract suprahyoid resistance, Poulton and Ware (1971) suggested the postoperative use of a neck brace. Bell et al. (1982) thought that preoperative neck hyperextension with a cervical collar would expedite suprahyoid neuromuscular adaptation. Previous studies (Tabary et al., 1972; Goldspink et al., 1974; Gonyea, 1978) cited by Bell et al. support the contention that muscles are capable of rapid adaptation in response to an altered environment.

Others (Steinhauser, 1973; Epker et al., 1978; Epker and Wessberg, 1982; Carlson et al., 1987) have favoured suprahyoid myotomy or division of the periosteal envelope (Guernsey, 1974) to alleviate soft tissue resistance in large mandibular advancements. Steinhauser (1973) described in detail, the intraoral detachment of the geniohyoid, anterior portion of the mylohyoid and anterior belly of the digastric muscles. Epker et al. (1978) performed myotomy if the suprahyoid muscles were stretched more than 15% of their resting length.

Several authors however, have raised doubts about the validity of suprahyoid myotomy (Poulton and Ware, 1971; McNeill et al., 1973; Schendel and Epker, 1980; Wessberg et al., 1982). Schendel and Epker's (1980) results showed that relapse was not controlled by myotomy and reasoned that the remaining attached soft tissues and muscles still provided a substantial relapsing influence. Wessberg and Epker (1981), Epker and Wessberg (1982) and Wessberg et al. (1982) agreed with this concept and referred to the relapsing effects of the paramandibular connective tissue tension. Wessberg (1981) defined the paramandibular connective tissues as "skin, interstitial connective tissues, periosteum, and muscles attached to or surrounding the mandible." MacIntosh (1981) did not believe that the suprahyoid or masticatory muscles primarily contributed to relapse. Instead he postulated that "the impetus for relapse comes from a proprioceptive drive (in the condylo-ramus-masticatory muscle complex) to reestablish the preoperative dento-oro-facial environment." However, MacIntosh failed to define the condylo-ramus-masticatory muscle complex and did not explain the role of proprioception.

From animal studies, Carlson et al. (1987) found that suprahyoid lengthening occurs at the muscle-tendon and muscle-bone interfaces in non-myotomy advancements. They concluded that suprahyoid myotomy was an acceptable procedure in selected cases but it could be avoided if stable fixation could be guaranteed. The findings of Carlson and Ellis verified the earlier theory of Poulton and Ware (1971) who thought either that "muscles have a range of tolerance in response to lengthening, rather than a fixed unalterable resting length or.....the muscles return to the presurgical resting length through migration of the bony and tendinous insertions."

The muscles of mastication have been discussed in some detail by Epker et al. (1978), Finn et al. (1980) and Bell et al. (1982). Epker et al. (1978) were of the opinion that these muscles exerted a considerable influence on the size, shape and spatial orientation of the mandible. They concluded that "the position of the muscles of mastication....are best left spatially unaltered when advancing the mandible. This is accomplished by the modified sagittal (split osteotomy)."

The study by Finn et al. (1980) sought to determine the biomechanical effects of mandibular and bimaxillary osteotomy by using a model which incorporated high mandibular plane angles. Because mandibular advancement decreases the mechanical advantage of the masticatory muscles, increased muscular activity would be expected in order to maintain equivalent biting forces. This increased activity would cause potential movement at the osteotomy and initiate relapse.

Finn et al. believed that the reorientation of the masticatory adductors and abductors created an unfavourable "force coupling" which caused a rotary movement at the osteotomy sites. Furthermore, the biomechanics following mandibular advancement unfavourably accentuated the coupling and force dissipation.

On the other hand, differential maxillary impaction and bilateral sagittal split osteotomy improved the mechanical advantage of the jaw adductors. Finn et al. explained the improved stability of bimaxillary cases by the decreased muscle activity resulting in fewer disruptive forces on the proximal segment. Will et al. (1984) did not feel that these biomechanics explained the phenomenon of relapse adequately enough as it excluded the more complex issues of length-tension relationships, motor unit recruitment and neuromuscular control after surgery.

Brammer et al., (1980) and Bell et al. (1982) agreed that less posterior mandibular relapse was observed with bimaxillary osteotomy. Posterior maxillary impaction "improves mechanical efficiency, increases autorotational advancement of the mandible, decreases absolute mandibular advancement and increases skeletal stability." According to Bell et al., the biomechanical principles of decreasing the lever arm of the bite point and increasing the adductor muscle lever arm were basic to postsurgical mandibular stability.

### *3.8. VIABILITY OF THE OSSEOUS SEGMENTS*

Epker et al., (1978) expressed concern that potential existed for avascular necrosis, delayed healing and subsequent bony instability with the conventional bilateral sagittal split osteotomy of Obwegeser (1957). They altered the procedure by limiting masseteric stripping and referred to the technique as the "modified bilateral sagittal split osteotomy." Stoelinga and Leenen (1981a) cited inadvertent damage to the inferior alveolar artery and the less vascular (thicker) cortical plates as possible causes of avascular necrosis. They concluded that only flap designs which maximised the mucoperiosteal pedicle should be used.

This concern was raised earlier by Grammer et al., (1974) who found that reduction in blood flow was sufficient to cause bony devitalisation following conventional bilateral sagittal split osteotomy. Path and his associates (1977) monitored blood flow in monkeys with a microsphere technique. When bilateral sagittal split osteotomy with complete stripping of the pterygomasseteric sling was done, they demonstrated significantly decreased perfusion to the anterior portion of the proximal segment. Grammer and Carpenter (1979) histologically confirmed that the conventional Obwegeser-Dal Pont bilateral sagittal split osteotomy compromised the blood supply to the proximal segment. They recommended the modified bilateral sagittal split osteotomy since it maintains "an adequate musculoperiosteal pedicle on the proximal fragment prevent(ing) avascular necrosis."

Worms et al., (1980) also agreed that poor blood supply or inadequate calcification could lead to a fibrous union. Reitzik (1983) and Martis (1984) attributed relapse to the immaturity of the bony callus and disharmony of the pterygomasseteric sling. Martis felt that minimal relapse occurred by conservative tissue stripping and the use of prolonged intermaxillary fixation whilst the osteotomies firmly united.

### *3.9. GROWTH AND RELAPSE*

The compensatory effect of growth on postsurgical relapse following correction of mandibular hypoplasia has been commented on previously by Schendel et al. (1978), Wolford et al. (1978) and Freihofer (1982). These authors concluded that adolescent growth in the postsurgical phase counteracted relapse tendency. They noted that subsequent dentofacial growth remained harmonious. In order to understand the skeletal growth changes which could affect relapse, a review of the literature was done. Mandibular growth has been extremely well documented in the orthodontic literature and a brief review of the most frequently reported changes is presented below.

The early work of Björk which commenced in 1951 involved 603 male cases between 12 and 20 years. This work (Björk and Skieller, 1983) showed that mandibular growth in normal subjects continues over a longer period compared to the maxilla. This was confirmed by several longitudinal studies involving both sexes (Lande, 1952; Pelton and Elasser, 1955; Downs, 1956; Subtelny, 1959; Coben, 1966; Nanda, 1974). Lande (1952) and Downs (1956) noted that as the mandible became more prognathic, the mandibular plane angle decreased. Lande (1952) studied 34 males from 7 to 17 years of age and found that the mandible became more prognathic in relation to the cranium during growth, but the maxilla showed little change. An interesting finding by Lande (1952) was that the majority of cases, regardless of dentoskeletal pattern, showed the same general tendencies in their growth behaviour.

Subtelny (1959) noted a decelerating change in the convexity of the skeletal profile. A change of only 5° in males and 2° in females occurred between 12 and 18 years of age compared to rapid changes in infancy (10° from 1 to 3 years). He found that girls had a slightly more convex profile than males during all growth periods. On the other hand, Mauchamp and Sassouni (1973) found that the female profile was slightly flatter than males by 2 to 3 degrees particularly at puberty. This difference between studies was thought to be due to a difference in the analysis and the use of different landmarks. A later study by Nanda (1974), found that boys had greater forward growth in the lower face during the pubertal period making their faces straighter and angular. Girls tended to have more rounded faces with slightly convex facial profiles.

Most studies consistently show that females commence and complete growth before males. Females experience minimal changes after 14 or 15 years of age whereas Downs (1956) found that males continue to develop until twenty. Brown et al. (1971) and Grave and Brown (1976) found that the average age at peak facial growth in boys ranged from 13.0 to 13.8 years and in girls, from 11.7 to 12.2 years (Figure 3.11). As a guide to mandibular anteroposterior growth, Wolford et al. (1978) extrapolated from their data that in females 90 per cent of growth was complete by 9 years, 95 per cent by 13 and 98 per cent by 15 years. By comparison, boys attained 85 per cent of growth by 9 years, 90 per cent by 13 years, and 98 per cent by 19 years.

Farrer (1984) summarised the findings of Baum (1961) who reviewed the effects of growth on the facial profile:

1. Males tended to grow more in all directions, commencing and finishing later in life (13-18 years). Most female growth occurs between 8-13 years and stops by 15 years.
2. Males attained relatively longer faces compared to females who display relatively deeper faces. Facial convexity flattened with age for both sexes but the effect was greater in males.
3. The faces of 12 year old females did not differ significantly from those at adulthood except in dimension. In contrast, the faces of 12 year old males underwent marked change by adulthood.

### 3.9.1. *The effect of surgery on growth of the mandible*

The interaction between growth and mandibular advancement surgery has been viewed from two different perspectives. Firstly, whether surgery retards subsequent mandibular growth and secondly, whether growth can compensate for postsurgical relapse. Several studies (Brodie, 1941, 1942; Broadbent, 1941; Sicher and DuBrul, 1970; and Emrich et al., 1965 cited by Schendel et al. 1978) indicate that mandibular deficiency in children will not resolve with growth. This has provided the rationale for early correction of mandibular hypoplasia.

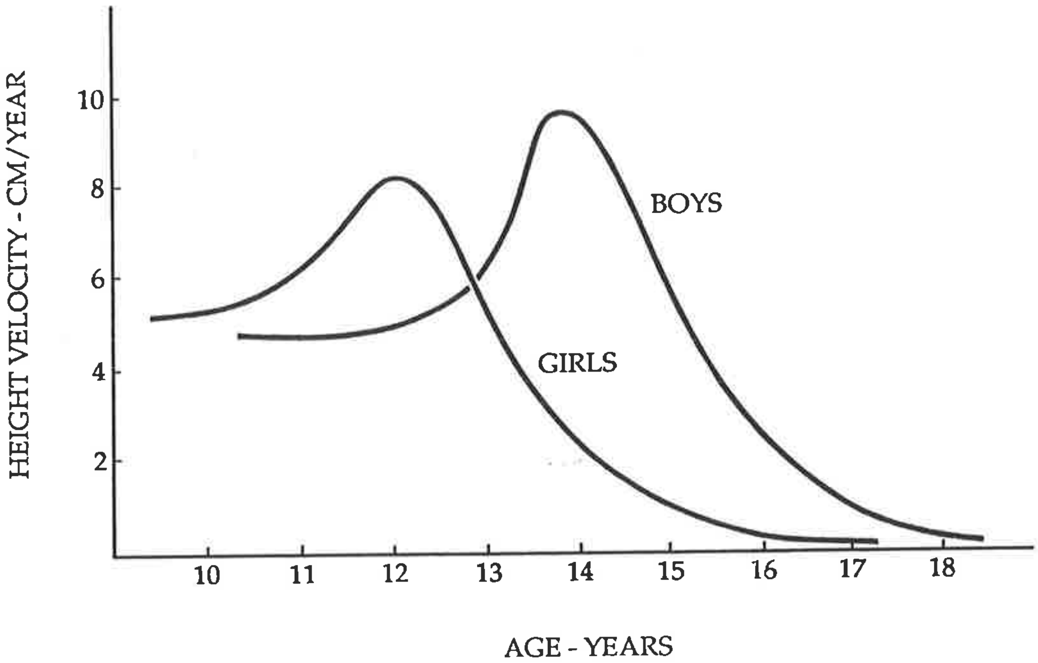



**Figure 3.11 : Average growth curves for males and females.**

**(From Grave and Brown, 1976)**

Schendel et al. (1978) concluded that dentofacial growth remained harmonious after bilateral sagittal split advancement. Twelve patients aged 8 to 16 years were reviewed over a postoperative period varying between 6 and 40 months. Freihofer (1982) reviewed 7 cases and agreed with Wolford et al. (1979) that early surgical intervention was possible in growing adolescents with mandibular hypoplasia. Any growth that occurred postoperatively would favourably compensate any relapse tendency. He noted that overgrowth of the mandible after lengthening has never been described.

Huang and Ross (1982) expressed concern that the bilateral sagittal split osteotomy was disruptive to mandibular growth. They selected 21 patients aged between 8.6 and 16.9 years, three of which had craniofacial anomalies and two others who had juvenile rheumatoid arthritis. Cases were followed for at least 2 years and were divided into type A (advancement 11-24 mm) or type B (advancement 1.5-8.5 mm). Mandibular length was measured from condylion to gnathion. Eight of the ten type A had additional advancement genioplasty and all but one type A were high angle (greater than $38^{o}$). Thus the sample was neither homogeneous or treated in a uniform manner. When 12 normal cases from 12.1-16.9 years of age were reviewed at one year, none of the patients showed further mandibular lengthening. However, a small amount ( mean 0.3 mm, range -2 to +2) was demonstrated after 24 months.

Carlson and Ellis (1988) were critical of the conclusions reached by Huang and Ross (1982) on several grounds. Since some of the patients had pathological conditions, the expectation of normal growth may not have been reasonable. Carlson and Ellis pointed out that differentiation between lack of mandibular growth and surgical relapse would be extremely difficult using conventional analytic techniques. As the majority of patients were in adolescence, the mandible may have grown normally but the amount of relapse cancelled the effect of growth. To investigate whether harmonious growth occurred after bilateral sagittal split advancement, Carlson and Ellis (1988) reported on a two year study with juvenile *Macaca mulatta* monkeys. They found that after 24 months, no untoward effects on facial growth was observed in the operated monkeys when compared with controls.

### 3.10. SUMMARY

The etiology of relapse is a contentious issue because consensus has not been reached regarding the individual role of various etiological factors. Numerous authors tend to agree that intraoperative condylar distraction, the magnitude of advancement, the method of fixation and soft tissue resistance are partly responsible for relapse. However, other factors, many unrecognised, undoubtedly contribute to relapse as demonstrated by the wide variation in individual relapse patterns.

Whilst the etiology of relapse has not been fully clarified, various surgical modifications have been proposed to reduce relapse. One of the most rapid developments has been in the method of fixation. Until recently, upper border wire osteosynthesis has been the established method of choice. However, well designed cephalometric studies (Lake et al., 1981; Sandor et al., 1984) have confirmed that relapse is still disappointingly high. The method of fixation has consequently undergone several transitions and bicortical screw fixation is currently favoured. Published results suggest a promising future for this modality of fixation (Kirkpatrick et al., 1987; Van Sickels et al., 1988).

The interaction between growth and mandibular advancement surgery has been of interest to several investigators. Huang and Ross (1982) expressed concern that the bilateral sagittal split osteotomy was disruptive to mandibular growth but Schendel et al. (1978), Wolford et al. (1978) and Freihofer (1982) concluded that dentofacial growth remained harmonious following mandibular advancement. Of great practical significance was the finding that mandibular growth in the postsurgical phase counteracted relapse tendency.

# CHAPTER 4

# ERRORS IN CEPHALOMETRY

## *4.1. INTRODUCTION*

Radiographic cephalometry represents one of the few convenient methods for acquiring dentoskeletal data in living subjects. Cephalometric radiography permits either cross-sectional or longitudinal (serial) evaluation of cranial changes (Brodie, 1955) and is a valid means of measuring the effects of surgical intervention. However, the use of any measurement technique is justified only when it can be shown that errors of estimation do not seriously affect true values (Brown, 1965).

The various sources of error inherent in cephalometry are well documented. Houston (1983) and Buschang et al. (1987) divided error into systematic and random patterns. Systematic errors introduced by the effects of observer and equipment bias pertain directly to the validity of the measurement. Brown et al. (1970) minimised systematic errors by standardising equipment and technique.

Observer bias arises from subconscious weighting of data collection. Random errors, or accidental errors, could arise as chance factors through variation in cephalostat positioning of the patient, film quality, landmark identification and equivocal landmark definition.

Gravely and Murray-Benzies (1974) classified errors as either "projection errors" or "tracing errors". Projection errors arise from the representation of the skull as a two dimensional radiograph and vary according to the film distances. Tracing errors arise primarily from incorrect landmark identification and measurement errors.

This basic classification can be subdivided into six categories:

1. errors of projection
2. errors of landmark identification
3. errors of digitising
4. errors of measurement
5. errors attributable to operator variability
6. errors of superimposition

### *4.2. ERRORS OF PROJECTION*

Many authors have recognised errors of projection and discussed ways of minimising these geometric errors (Adams, 1940; Thurow, 1951; Hallett, 1959; van Aken, 1963; Salzmann, 1964; Wisth and Böe, 1975; Moyers and Bookstein, 1979; Bergersen, 1980; Eliasson et al. 1982; Ahlqvist et al. 1983). In a comprehensive review, Bergersen (1980) summarised these compensatory mechanisms and further suggested the use of compensation tables for linear measurements.

Carlsson (1967) clearly stated the etiological factors of projection errors as "those arising in the projection of the skull, and including the enlargement, departures from parallelity between the median and film planes, especially when the patient is fitted on the cephalostat, deviations on the position of the focus in relation to an imaginary line through the ear rods, and geometric unsharpness due to the area of focus."

Baumrind and Frantz (1971a) published a comprehensive series on the reliability of head film measurements. In addition to the errors of projection mentioned by Carlsson (1967), head films distorted through "foreshortening of distances between points lying in different planes and by radial displacements of all points and structures not on the principal axis." Eliasson et al. (1982) and Ahlqvist et al., (1983) agreed that major errors could arise from misalignment of the x-ray source, the cephalostat, the film or the subject.

Despite this apparent potential for error, Carlsson (1967) found that the geometric errors of projection were small in relation to the total error of the method. Ahlqvist et al. (1986) similarly concluded from theoretical calculations, that projection errors in length measurements were minor in cephalometry. Head rotation of ± 5° results in an error of less than 1%. Rotation or tilting of the head greater than 5° would cause significant error however, this rotation should be obvious to the observant radiographer and corrected. Houston et al. (1986) confirmed the opinions of Björk (1947), Solow (1966), Midtgård et al. (1974) and Ahlqvist et al. (1986) that projection errors were acceptably low if radiographs were taken with care.

### *4.4. ERRORS OF LANDMARK IDENTIFICATION*

Errors in landmark identification have generated an enormous amount of discussion (Björk, 1947; Hixon, 1956; Hatton and Grainger, 1958; Miller et al., 1966; Richardson, 1966; Savara et al., 1966; Brown et al., 1970; Baumrind and Frantz, 1971a; van der Linden, 1971; Midtgård et al., 1974; Broch et al., 1981; Richardson, 1981; Stabrun and Danielsen, 1982; Houston, 1983; Phillips et al., 1984; Chate, 1987; Savage et al., 1987; Vincent and West, 1987).

Graber (1958), Miller et al. (1966), Broch et al. (1981), Houston (1983) and Chate (1987) remarked that the greatest source of random error is imprecise landmark identification and inaccuracy of landmark definition. Baumrind and Frantz (1971a), Miller and Baumrind (1973), Houston (1983) and Savage et al. (1987) encouraged more precise landmark definitions to reduce error. However, no consensus on landmark definition has been reached. The problem is compounded by extremal landmarks (Moyers and Bookstein, 1979) which are defined by the maximum or minimum of some geometric property. Thus menton or pogonion could change position depending upon the horizontal reference plane and the amount of jaw opening, despite rigorous adherence to the landmark definition.

Savara et al. (1966) calculated that the variability of landmark location was five times that due to measurement. Brown (1973) remarked that landmarks which were difficult to locate radiographically would almost certainly lead to inflated variance estimates even though mean values showed only minor discrepancies. Broch et al. (1981) found that landmark identification varied for 15 tested points according to a characteristic envelope of error as reported by Richardson (1966) and Baumrind and Frantz (1971a). Broch et al. (1981) concluded that "the reliability of the landmark identification depends on five factors: characteristics of the cranial structures, the general quality of the headplate, blurring of the anatomical structures caused by secondary radiation or movement during exposure, precision of the recording method and the accuracy of the operator."

In longitudinal radiographic studies of the same subject, local variations in the bone configurations (due to specific growth changes) influence both landmark identification and measurement variability (Järvinen, 1987). This is in agreement with Sekiguchi and Savara (1972) and Savara and Takeuchi (1979) who reported that individual morphological variations caused by growth affected the radiographic image and subsequent landmark determination. Järvinen (1987) also concluded that jaw closure increased variability by rotating mandibular structures into a different position.

Baumrind and Frantz (1971a) explained that landmark identification depends on interpretation of the definition for the landmark, whether the landmark falls on a gradual curve or sharply defined point and how superimposition of adjacent structures affects the image sharpness. They found that machine porion, sella and upper incisor edge were the most reproducible landmarks. Gonion and lower incisor root apex were considered the least reliable landmarks. Significant gains in accuracy could be expected by performing a second independent series of measurement and calculating the mean. Savage et al. (1987) performed double determinations on 18 landmarks and found that sella, pogonion and gnathion had the lowest coefficient of variation and porion and basion the highest. Surprisingly in their series, there was no statistical difference between constructed and directly determined bony landmarks.

Hurst et al. (1978) assessed whether xeroradiography enhanced landmark identification. From 14 landmarks, Down's A point, upper incisal tip, infradentale and menton were more accurately determined with xerograms. However, conventional cephalograms delineated Down's B point and condylion more accurately. In reviewing the literature, Vincent and West (1987) cited the findings of Gravely and Murray-Benzies (1974), Halse and Hedin (1978) and McWilliam and Welander (1978) who agreed that film quality was not paramount in landmark error.

Houston (1983) believed that the best way to reduce random error was to do duplicate tracings since the greatest errors arose from point identification rather than from measurement. Baumrind and Miller (1980) recommended four replicate measurements using computer-based digitising. Richardson (1966), Baumrind and Frantz (1971a) and Midtgård et al. (1974) showed that the time interval between the first and second determination did not affect reproducibility. The importance of routine double determinations was considered less important by Brown (1973) provided that the measuring techniques were carefully standardised and the observer had progressed through a series of double determinations to assess personal replicability. Brown et al. (1970) described the application of least squares transformation and measured a 51% reduction in discrepancies in point location made on tracings. This method is not restricted by film orientation and allows differential weighting of consistently identifiable and stable landmarks.

### *4.4. ERRORS OF DIGITISING*

Errors associated with digitising are minimal. Bergin et al. (1978), Broch et al. (1981), Bondevik et al. (1981) and Richardson (1981) concluded that when a digitiser is used the only source of error is landmark identification. Broch et al. (1981) examined the error associated with replicating the coordinate system and found that the error was negligible (0.03 mm) for both axes. A similar range of error was reported by Savage et al. (1987) in their study of cephalometric points.

Richardson (1981) compared traditional and computerised methods of cephalometric analyses using standardised films from 50 subjects. He found that whilst the computer offered enormous advantages in terms of speed and data preparation, traditional measurement compared well in terms of accuracy. This occurred because many of the anatomical landmarks could not be located with a degree of precision to match the resolution of a digitiser. However, in a similar study by Houston in 1982 (cited by Savage et al. 1987), the precision of point registration and linear and angular measurements was superior when digitising was employed.

### *4.5. ERRORS OF MEASUREMENT*

Measurement errors have virtually been eliminated by the routine use of digitising procedures in research (Broch et al., 1981; Bondevik et al., 1981). However, in the clinical setting, digitisers and computers are not routinely used and manual mensuration is subject to error. Carlsson (1967) examined manual errors by direct measurement from lateral head films. He found small but statistically significant differences in mensuration for rulers graduated in 0.5 mm and calipers graduated in 0.1 mm increments. Baumrind and Frantz (1971a, 1971b) believed that measurement error was frequently underestimated but could be reduced by using digitising, performing a second independent series of measurement and calculating the mean. Björk (1947) found that errors in angular and linear head film measurement arose from errors of projection, errors of landmark location and mechanical errors in drawing lines between points on tracings and on measuring with ruler or protractor.

Midtgård et al. (1974) investigated seven cranial distances by digitised double determinations of 25 tracings. They considered that the variance of the error as a percent of the total variance should not exceed 3 percent. Two of the distances (n-ss and n-sm) exceeded this value and was related to the uncertainty of landmark identification.

Bergersen (1980) discussed the importance of enlargement compensation and described a method to accurately calculate distances based on structures which did not lie on the midsagittal plane. He combined a lateral and frontal cephalogram and used triangulated areas to obtain the desired measurement. Errors in all measured planes did not exceed 0.7%. From these findings Bergersen was able to construct compensation tables for accurate interpretation.

### *4.6. INTRA-OBSERVER AND INTER-OBSERVER VARIABILITY*

Technical errors exist both within observers (Björk, 1947; Solow, 1966; Richardson, 1966; Stabrun and Danielsen, 1982) and between observers (Richardson, 1966; Mattila and Haataja, 1968; Gravely and Murray-Benzies, 1974; Baumrind and Frantz, 1971b; Vinkka and Koski, 1974; Richardson, 1981; Stabrun and Danielsen, 1982; Vincent and West, 1987). Broadway et al. (1962) used 40 subjects to examine the intra-observer and inter-observer errors in tracing lateral head films. Very small errors were found for replicate measurements by the same observer whereas measurement errors were increased between observers. These conclusions have been confirmed by most studies and appear related to the observer's opinion of the landmark location (Savage et al., 1987).

Stabrun and Danielsen (1982) evaluated the ability of two observers to identify certain cephalometric landmarks using 100 cephalograms. Fourteen landmarks were assessed as having a characteristic distribution reflecting the ease with which a landmark could be located. Inter-observer variability was considerable despite pre-registration training. The intra-observer data indicates that each observer holds definite opinions as to the landmark localization resulting in apparently improved precision. From the majority of studies, it can be concluded that measurement data from cephalograms should be collated by one experienced observer.

### *4.8. ERRORS OF SUPERIMPOSITION*

In commenting upon superimposition of tracings, Baumrind et al. (1976) emphasised the effects of primary and secondary errors. Primary errors in a line segment result from rotation, translation or a combined effect. These errors originate from an attempt to achieve biological best fit and are dependent upon the judgement of the investigator. Secondary errors are systematically related to the primary errors and therefore are mathematically defined. Distant landmarks are particularly sensitive to primary rotational errors and produced a larger proportion of the total error. A landmark which lies 100 mm from the centre of rotation with a rotational error of only 1 degree results in a displacement of 1.74 mm.

Houston and Lee (1985) compared several popular methods of superimposition on cranial base structures. They concluded that each method of superimposition had an appreciable error which could be misinterpreted as dentoskeletal change. Therefore they emphasised that every serial study should clearly report the method error of superimposition.

The use of fiducial landmarks by Baumrind and Frantz (1971a) has gained widespread acceptance as a method of transferring registrations from one film to another (Broch et al., 1981; McWilliam, 1982b; Stabrun and Danielsen, 1982; Vincent and West, 1987). Vincent and West used a pin punch register system to minimise the registration error associated with superimposition. This method required only one point to be digitised thereby decreasing the potential for error in superimposition.

Several other techniques have been described, most notably by Sluiter et al. (1985). They eliminated fiducial landmark superimposition by using computer transformations. This simplified approach leaves the films undamaged since it only relies on the sides of the film for registration. The computer calculates the vector of displacement and rotation of the superimposed film. The authors reported an extremely low magnitude of error.

McWilliam (1982a, 1983) proposed the use of subtraction superimposition to overcome superimpositional errors. Using 22 growing subjects, he reported an improvement on the results of Baumrind et al. (1976) of 47% and 16% for $x$ and $y$ coordinates respectively. Houston and Lee (1985) were critical of the cost of this method and found it impractical for routine clinical use. However, they concurred that its improved reproducibility would be useful in research.

### *4.9. THE SELECTION OF A SUITABLE LINE OF REFERENCE*

The selection of a suitable line of reference in cephalometry is a continual source of debate. A succession of authors (Björk, 1947; Brodie, 1949; Krogman, 1951; Lande, 1952; Taylor, 1969) have discussed the advantages and disadvantages of frequently used lines of reference without clear consensus. According to Steiner (1953) and Wei (1968), the ideal line of reference should:

1) superimpose easily
2) remain perfectly stable despite growth so that craniofacial variations elsewhere can be clearly demonstrated
3) be based on reference points with an infinitesmal envelope of error which does not vary when the head deviates from the true profile position.

Although the ideal cephalometric reference line does not exist, several lines have been suggested with recognition of their limitations. The main limitation is that there are no absolutely fixed points in the growing head and face, only relatively stable points (Krogman, 1951). Historically, the difficulty in selecting a suitable line of reference in cephalometry was clearly reflected in the decision of the Second Research Workshop on Roentgenographic Cephalometrics (Salzmann, 1960, 1964) to adopt three cranial reference lines: the Bolton line, the spheno-occipital synchondrosis-nasion line and the nasion-sella line. The basis for the decision was that each line held several advantages but none of the lines was clearly superior to the other.

Most investigations in the recent orthognathic literature refer to the Frankfort horizontal, the nasion-sella line or its variant, the SN-7 line (Burstone, 1978). This last line was popularised by Burstone and his colleagues who based their orthognathic package, the COGS (Cephalometrics for Orthognathic Surgery) system, on the SN-7 line. These lines are illustrated in Figure 4.1.

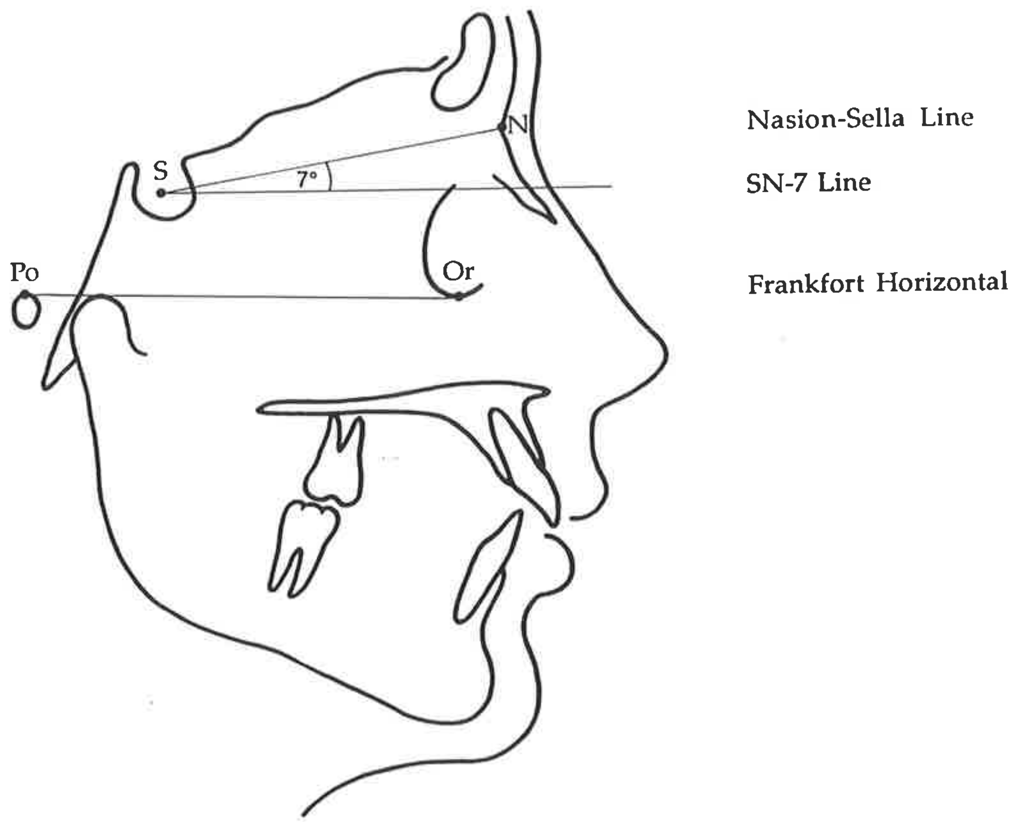



**Figure 4.1 : Reference lines referred to in the text**

### *4.9.1. The Frankfort horizontal*

The Frankfort horizontal line was first defined by von Ihering (1872) as passing through the centre of each auditory meatus and lower margin of the respective orbits (Finlay, 1980). This description was adopted with minor modification by the anthropological congress in 1884 (Krogman, 1958). Thus, the Frankfort horizontal is defined as a line passing through the upper periphery of the external auditory canals and the lowest point of the left orbit. This line has become firmly entrenched in the literature due to its straightforward application in the clinical setting and its close approximation to the natural head position (Bjerin, 1957).

However, Frankfort horizontal line is regarded by several authors to have significant cephalometric limitations. Krogman (1951) stated that the strength of the Frankfort horizontal lay in its use as a universal "plane" of orientation rather than a "plane" of superimposition. Downs (1952) found that porion was poorly distinguished radiographically and that it was erroneous to assume that it rests level with the ear rods. "Porion is approximately 3 mm above the ear rod when the head is correctly positioned in the cephalometer." The fact that the tissues of the ear are readily compressible and the external auditory meati are not always symmetrical may cause technical errors.

Because of the problems with machine porion, Ricketts (1981) stressed the use of the Frankfort horizontal based upon the location of true porion rather than the ear rod. "The ear rod has been noted to be located well over 1 cm from the true ear hole." Ricketts remarked that true porion usually lies 3 to 4 mm downwards and forward from the internal auditory canal and superior to basion and the dens. The top of the condylar head is usually close to the level of the true porion. Koski and Virolainen (1956) admitted that even the use of anatomical porion was not entirely satisfactory. "The oval shadow visible in the roentgenogram may be a cross-section of some inner part of the meatus and the exact location of the point is impossible to determine."

Chate (1987) acknowledged the inadequacies of identifying structures, such as porion, within the petrous temporal region. Reliable identification was affected by the anatomical complexity and structural superimposition (Martinoni, 1978). Cephalostat ear rods tended to compound the problem by obscuring anatomical porion. Chate noted that radiographic porion actually lies postero-superiorly to the true anatomical porion as defined by lead markers.

### 4.9.2. *The nasion-sella (Broadbent) line and the SN-7 line*

The Broadbent or nasion-sella line extends from nasion, the most anterior point on the nasofrontal suture, to sella, the midpoint of the sella turcica located by visual inspection (Krogman, 1951). In presenting his findings on the variability of roentgenographic cephalometric lines of reference, Wei (1968) wrote that "as there is no 'fixed point' or absolutely stable line in a growing organism, the line which varied least in comparison with others should become the one of choice." Wei concluded that the nasion-sella line was the least variable and was the line of choice.

Brodie (1941, 1953) had concluded earlier that the nasion-sella line provided a stable reference against which facial growth could be monitored. He showed that the angular change between basion-sella-nasion from 4 to 18 years of age was less than 4° in thirty subjects.

Steiner (1953) was convinced that the nasion-sella line was superior to the Frankfort horizontal in orienting cephalometric tracings. "Points Sella and Nasion are clearly visible in the x-ray pictures and can be located easily and accurately....(They) are located in the midsagittal line of the head and therefore they are moved a minimum amount whenever the head deviates from the true profile position."

Bjerin (1957) examined the relationship between the Frankfort horizontal and nasion-sella line to the postural horizontal. His results showed that both lines had a similar standard deviation and therefore recommended using nasion-sella line, as its landmarks were easier to determine.

However, Baume (1957) argued that sella was dependent upon the growth of the spheno-occipital synchondrosis and pituitary gland. Furthermore, studies by Keith and Campion, (1922), and Scott (1953) showed that a superior migration of nasion occurred with growth. Ford (1958) was critical of the nasion-sella line, as it traverses different independent morphological and functional components of the cranial base (Figure 4.2).

Björk and Skieller (1983) and Buschang et al. (1986) selected nasion-sella line with some qualification in their longitudinal study. Björk and Skieller (1983) remarked that in longitudinal growth studies nasion and sella may be displaced by growth. An upward displacement of nasion was possible with growth at the frontonasal suture. Remodelling of the pituitary fossa associated with the enlarging pituitary gland could cause a posterior displacement of sella. Björk and Skieller therefore relied upon superimposition on cranial base structures transferred from the original film. The anterior wall of sella was favoured in registration as Melsen (cited by Björk and Skieller) has shown that the contour of this structure undergoes minimal remodelling.

This stability and the stability of other anterior base structures after 10 years of age formed the basis of Björk and Skieller's method of superimposition. The altered vertical position of nasion due to growth was projected onto the transferred nasion-sella line. Vertical orientation was assisted by the observation "that towards the end of the juvenile period, the inner surface of the frontal bone is stable over a short period in relation to the anterior cranial base and to the sella point."

Björk (1955) found that the outer surface of the frontal bone contributed to facial growth rather than the inner plate. Thus, forward extension of the anterior cranial fossa ceased at approximately 10 years and the shape of the fossa remained constant from 12 to 20 years in the ethmoid region. Björk consequently advocated the use of nasion-sella line during adolescence because of its constancy (90% of cases) in the relation between SN and the deepest median contour of the anterior cranial fossa.

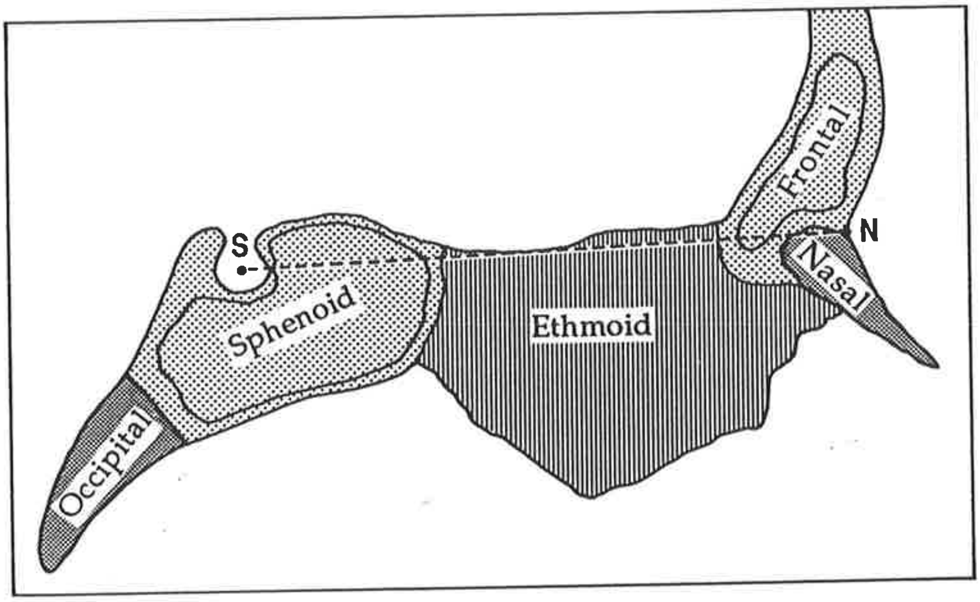



**Figure 4.2 :** **Sagittal section showing contributing structures in the line connecting sella and nasion**

Growth of almost 2.5 mm per year along the nasion-sella line was held by Ricketts (1960) to be a grave indictment of the nasion-sella line as a reference line in longitudinal studies. This growth in pubertal males appeared to occur at the frontonasal region. In marked contrast, Nanda (1955) reported that the dimension sella-nasion, showed the smallest percentage change between 10 and 17 years when compared to several other craniofacial dimensions.

In addition to the problems with growth, Baumrind and Frantz (1971b) pointed out that the weakness in the superimposition at sella-nasion stems from the occasional large errors in the vertical location of nasion. Richardson (1966) commented that the suitability of a landmark in a study should depend upon its reproducibility. For example, nasion ranked highly in the horizontal line but was less reproducible in the vertical line when assessed by mean, standard deviation and 95% confidence levels. Despite this elliptical envelope of error, nasion-sella line ranked highly, second only to maxillary line for 95% limits and third by standard deviation.

Notwithstanding these limitations, Wei (1968) showed that the nasion-sella line was the least variable of five reference lines, investigated after the method of Koski and Virolainen (1956). Wei concluded that the nasion-sella line held the advantages of accurate location, ease of superimposition and ease of comparison over other lines, including Frankfort horizontal.

Baumrind et al. (1976) tested the reproducibility of superimpositions on the nasion-sella line and anterior cranial base. From one hundred superimpositions by 4 experienced judges, they concluded that either method was acceptable. An interesting finding was that the rotational error was higher for nasion-sella line superimposition. These rotational effects produced a larger proportion of the total error.

Ghafari et al. (1987) found that there were minimal differences between superimposition of tracings on sella-nasion line registering at sella compared to anterior cranial base superimposition as proposed by de Coster (1952), Björk (1960) and Björk and Skieller (1983).

In contrast, Pancherz and Hansen (1984) found that superimposition on cranial base structures was less accurate compared to superimposition at nasion and sella when constructing the nasion-sella line. This was attributed to the intricate and time-consuming process of aligning the delicate cranial base structures which were readily affected by variation in film density, sharpness and projected geometric distortions. Registration error led to significant differences in the selected angular and linear measurements.

Houston and Lee (1985) compared several methods of superimposition on cranial base structures. These were:

1) the direct superimposition of radiographs (Björk and Skieller, 1983)
2) superimposition of tracings (Baumrind et al., 1976; Ekström, 1982)
3) the Adams Blink Comparator (Kerr, 1978)
4) a subtraction method to register pairs of cephalometric radiographs (Lee, 1980; McWilliam, 1982a)
5) the sella-nasion line of each radiograph

They found that the nasion-sella line had a lower method error than cranial base superimposition and was less sensitive to the quality of the radiograph.

Despite the advantages of the nasion-sella line over Frankfort horizontal it suffers from a distinct clinical disadvantage in orthognathic surgery. The use of the nasion-sella line as a horizontal line of reference does not orientate the cephalogram to the postural horizontal of the patient.

In proposing the SN-7 line in 1978, Burstone and his associates described the line as a surrogate Frankfort horizontal. This line exploits the advantages of the nasion-sella line whilst favourably reorientating the head so that the influence on extremal landmarks is markedly reduced. By convention, SN-7 originates from nasion, however, it can also be drawn forward from sella (Marcotte, 1981).

Literature related to the SN-7 line is scant particularly in regard to the 7° angulation. Marcotte (1981) stated that "the SN-7 line has been shown to be, on the average, fairly close to the anatomical Frankfort horizontal....." The findings of a number of studies tend to support this view. Koski and Virolainen (1956) measured a mean difference (and standard error) of 6.8° (0.26) between nasion-sella line and Frankfort horizontal based on 100 cephalograms. Bjerin (1957) used 210 cephalograms from 35 patients to show that a difference of approximately 6 degrees existed between nasion-sella line and Frankfort horizontal. In Wei's presentation (1968) of the variability of reference lines, a mean difference of 7.2 ± 0.42° for 50 male subjects was reported. Although individual variation was reported in each study, the standard errors of the mean were relatively low. This suggests that the SN-7 line is an acceptable horizontal reference line which retains the benefits of the nasion-sella line for superimposition.

It is concluded whilst no single line of reference fulfils ideal criteria, the nasion-sella line is well established in the literature and has several advantages. It varies little compared to other facial lines, its end points are relatively easy to locate and are affected least by sagittal rotation of the head. Furthermore, the method of superimposition is relatively simple and it has low method error. The disadvantage of variations arising from growth has been minimised in longitudinal studies by the superimposition method of Björk and Skieller (1983). The line SN-7 was chosen for superimposition in this study as it favourably reorientates the lateral cephalometric profile and retains the benefits of the nasion-sella line.

# III

# Materials and Methods

# CHAPTER 5

# MATERIALS AND METHODS
# EVALUATION OF POSTSURGICAL SKELETAL RELAPSE

### *5.1. SELECTION OF PATIENT RECORDS*

Records were retrieved from the Oral and Maxillofacial Surgery Unit, The University of Adelaide, for all patients who underwent surgical advancement of the mandible via the modified bilateral sagittal split osteotomy (Dal Pont, 1961; Epker, 1977). Seventy patients with a diagnosis of mandibular hypoplasia in the sagittal plane were treated at the Royal Adelaide Hospital between 1985 and July, 1988 by 6 surgeons who followed the same operative technique. The Caucasian patient sample was drawn from the metropolitan area of Adelaide. Socioeconomic bias influenced the sample as patients were only eligible for treatment if they held health care cards (school students, unemployed, sickness benefits).

Cephalometric records were accepted into the study if they met the following criteria:

1. at least one year postsurgical follow-up
2. surgery was limited to bilateral sagittal split osteotomy or combined with Le Fort I maxillary osteotomy
3. availability of lateral head cephalometric radiographs preoperatively and at arbitrarily defined postsurgical intervals:

    T1: at completion of presurgical orthodontics
    T2: within three days postsurgery
    T3: approximately six weeks postsurgery
    T4: approximately 12 months postsurgery

A total of 40 patient records, consisting of 180 radiographs, were accepted. All of the patients received presurgical and postsurgical orthodontic treatment through the Department of Orthodontics at the Adelaide Dental Hospital. A subset of patients (N = 20) was reviewed regularly for a minimum period of two years. This category was designated T5.

T5: the most recent lateral head cephalogram taken a minimum 24 months postsurgery.

The age at which each patient underwent surgery was calculated from their date of birth to the nearest month (Table 5.1). The records were assigned to either screw fixation (SF: N = 18) or wire osteosynthesis (WF: N = 24) groups and subdivided if additional Le Fort I osteotomy was performed (Tables 5.2 and 5.3). Each group was further subclassified by sex to establish whether sexual dimorphism could be shown.

**Table 5.1. Age and sex distribution of patients undergoing surgery**

| *Sex* | *Number* | *Mean Age (yrs)* | *Std. Dev.* | *Min.* | *Max.* | *Range* |
|---|---|---|---|---|---|---|
| **Male** | 11 | 18.1 | 2.94 | 14.6 | 24.7 | 10.1 |
| **Female** | 29 | 19.8 | 4.35 | 13.0 | 27.8 | 14.8 |
| **Total** | **40** | **19.2** | **3.99** | **13.0** | **27.8** | **14.8** |

**Table 5.2. Distribution of patients assigned by method of fixation and surgical procedure**

| *SCREW FIXATION* | | | | | | |
|---|---|---|---|---|---|---|
| *Group 1: Bilateral sagittal split osteotomy* | | | | | | |
| *Sex* | *Number* | *Mean Age (yrs)* | *Std. Dev.* | *Min.* | *Max.* | *Range* |
| **Male** | 3 | 18.9 | 5.23 | 14.6 | 24.7 | 10.1 |
| **Female** | 7 | 18.4 | 4.00 | 14.5 | 23.9 | 9.4 |
| **Total** | **10** | **18.5** | **4.08** | **14.5** | **24.7** | **10.2** |
| *Group 2: Bimaxillary osteotomy* | | | | | | |
| **Male** | 1 | 18.2 | | | | |
| **Female** | 7 | 20.8 | 4.71 | 13.0 | 26.3 | 13.3 |
| **Total** | **8** | **20.5** | **4.45** | **13.0** | **26.3** | **13.3** |

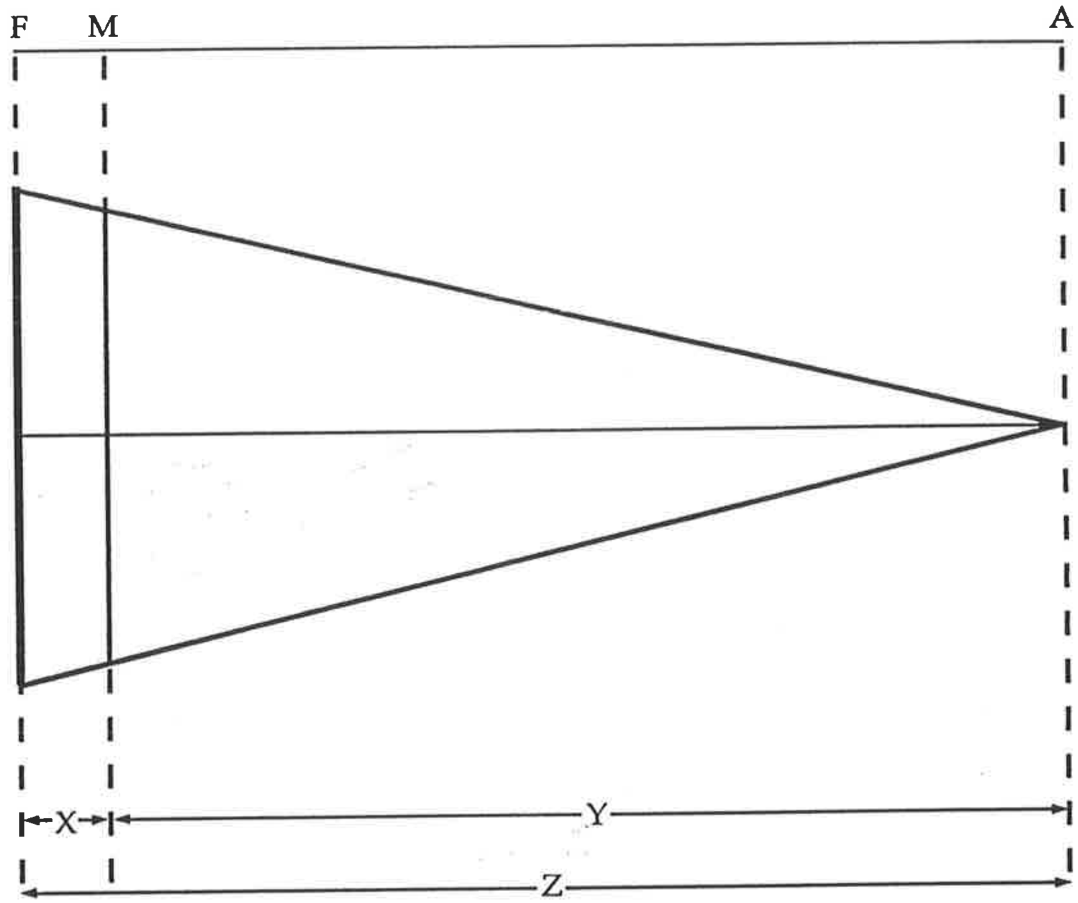
**Table 5.3. Distribution of patients assigned by method of fixation and surgical procedure**

| *WIRE FIXATION* | | | | | | |
|---|---|---|---|---|---|---|
| *Group 3: Bilateral sagittal split osteotomy* | | | | | | |
| *Sex* | *Number* | *Mean Age (yrs)* | *Std. Dev.* | *Min.* | *Max.* | *Range* |
| **Male** | 4 | 17.7 | 2.50 | 15.2 | 21.8 | 6.6 |
| **Female** | 8 | 17.1 | 3.05 | 13.0 | 22.1 | 9.1 |
| **Total** | **12** | **17.3** | **2.78** | **13.0** | **22.1** | **9.1** |
| *Group 4: Bimaxillary osteotomies* | | | | | | |
| **Male** | 3 | 17.2 | 2.44 | 15.5 | 20.0 | 4.5 |
| **Female** | 7 | 21.3 | 3.72 | 18.8 | 27.8 | 9.0 |
| **Total** | **10** | **19.7** | **3.75** | **15.5** | **27.8** | **12.3** |

### 5.2. *RADIOGRAPHIC TECHNIQUE*

Radiographs were taken by the Radiology department at the Adelaide Dental Hospital using *TMAT 6, Ortho M* or *Cronex Lodose* film. The film, selected at the discretion of the radiographer, was inserted into a *Kodak Lanex* regular cassette with *Kodak Lanex* regular screens. The cassettes were slotted into a *Kodak Lanex* film holder. A film-midsagittal plane distance of 16 cm was used for all cases.

A standardised technique for lateral head cephalograms was followed (Farrer, 1984). The patients were gently secured by a *Lumex* cephalostat (Copenhagen) in the Frankfort horizontal position whilst standing upright. An aluminium wedge filter was aligned with the soft tissues of the face. Head orientation was checked by using vertical and horizontal light beams. Patients were instructed to bite gently on their back teeth and maintain a relaxed lip posture (Burstone, 1967; Hillesund et al. 1978). A *Philips Super 50 CP/80 CP* microprocessor-controlled unit was used to generate x-rays. Films were processed automatically with a *Kodak RP X-OMat* film processor. The enlargement factor of 8.8% (Figure 5.1) was calculated by Farrer (1984) in a previous study using the same radiographic facilities.




F = Film plane

M = Mid-sagittal plane

A = Focus

X = 160 mm

Y = 1818 mm

Z = 1978 mm

E = Enlargement Factor

$$E = 100 \times \left[\frac{Z}{Y} - 1\right]$$

$$= 100 \times \left[\frac{1978}{1818} - 1\right]$$

$$= \underline{8.8\%}$$

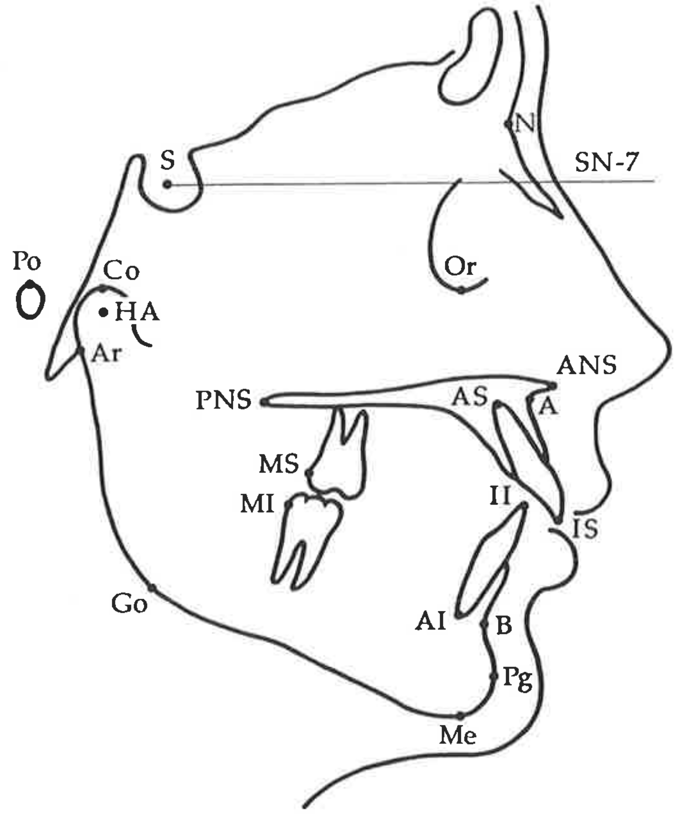
**Figure 5.1 : Calculation of the enlargement factor for points lying on the mid-sagittal plane. (X, Y, Z drawn to scale).**

### 5.3. *TRACING AND DIGITISING PROCEDURE*

Each radiograph was placed over a fluorescent light box in a darkened room. A black cardboard frame was placed around the perimeter of the film to eliminate extraneous light. Hard tissue details were recorded on *Ortho Trace* 0.08 mm matte acetate sheet with a sharp HB lead pencil. A 10 cm line was constructed on the presurgical (T1) film seven degrees to the nasion-sella line with origin at sella. The location of each cephalometric point was determined with the film orientated to the SN-7 line (Figure 5.2).

A mandibular template from the presurgical (T1) radiograph was used to transfer points condylion (Co) and gonion (Go) by superimposition on the proximal segment of each postoperative cephalogram (Kohn, 1978; Lake et al., 1981). Menton (Me), pogonion (Pg) and Down's B point (B) were also transferred using the mandibular template to maintain the relative position of extremal points. Where an occlusal wafer was present postoperative radiographs were corrected by rotating a mandibular template at hinge axis (HA) until the incisal tips came into contact (Kirkpatrick, 1987). This eliminated the anterosuperior mandibular rotation usually associated with occlusal wafer removal. Changes seen at T2 or T3 were recorded with the mandible in this corrected position.

The acetate tracings from each radiograph were digitised on a *Hewlett Packard* 9874A digitiser configured to an *Apple IIe* computer. Tracings were orientated to the SN-7 line on the digitiser tablet and secured with cellulose tape. The software program, *Cephs Compare* developed for cephalometric research by Brown (1986, personal communication), was programmed to record individual patient details, accept each digitised record and "transform" cartesian coordinates relative to the SN-7 line registering at sella. Alphanumeric data relating patient details and the magnification factor were entered. Magnification of 8.8% was not corrected. Each nominated point was centrally aligned in the large window cross-hair cursor and registered by depressing a perimeter button on the cursor. Data was transformed automatically by the computer and saved to disk for editing. All tracing and digitising procedures were carried out by the one person.




| | | | | | |
|---|---|---|---|---|---|
| 1 | S | Sella | 10 | Pg | Pogonion |
| 2 | N | Nasion | 11 | B | Down's B point |
| 3 | Po | Porion | 12 | AI | Lower incisal apex |
| 4 | Or | Orbitale | 13 | II | Lower incisal tip |
| 5 | Co | Condylion | 14 | IS | Upper incisal tip |
| 6 | HA | Hinge axis | 15 | AS | Upper incisal apex |
| 7 | Ar | Articulare | 16 | A | Down's A point |
| 8 | Go | Gonion | 17 | ANS | Anterior nasal spine |
| 9 | Me | Menton | 18 | PNS | Posterior nasal spine |
| | | | 19 | MS | Upper molar crown |
| | | | 20 | MI | Lower molar crown |

**Figure 5.2 : Hard tissue points listed in order of digitising sequence**

### 5.4. *REFERENCE POINTS AND LINES*

Reference points and reference lines (Figures 5.2 and 5.3) throughout the text were selected from the Adelaide Oral and Maxillofacial Surgery Unit handbook (1983) and from the *Quick Ceph* manual (1986). Definitions were derived from several sources and referenced accordingly. Cephalometric points which relied on bilateral radiographic structures (porion, orbitale, pterygoid, condylion and gonion) were taken as the midpoint where the two images did not coincide.

#### 5.4.1. *Hard tissue points (Fig. 5.2)*

**Sella (S)**: the centre of the pituitary fossa of the sphenoid bone determined by inspection (van der Linden, 1971; Vincent and West, 1987).

**Nasion (N)**: the most anterior point of the frontonasal suture (Brown, 1973).

**Porion (Po)**: the most superior point on the external auditory meatus (Koski and Virolainen, 1956; Ricketts, 1979; Savara and Takeuchi, 1979; Pancherz and Hansen, 1984; Wolford, Hilliard and Dugan, 1985; Blaseio, 1986; Vincent and West, 1987). The external auditory meatus has three radiolucent areas which distinguish it from the internal auditory meatus: the fenestrum vestibulae superiorly, the fenestrum cochlea posteriorly and the promontory anteriorly (Yen, 1960).

**Orbitale (Or)**: the lowest point on the average of the right and left borders of the bony orbit (Riolo et al., 1974).

**Condylion (Co)**: the most superior point on the head of the condyle (Tracy and Savara, 1966; Sekiguchi and Savara, 1972; Brown, 1973; Lake et al. 1981; McNamara, 1984; Smith et al., 1985). Several authors, notably Björk and Palling (1954) have defined condylion as the most supero-posterior point on the head of the condyle. It is determined as the point of tangency to a perpendicular construction line to the anterior and posterior borders of the condylar head. Condylion, therefore is located as the most superior axial point of the condylar head rather than as the most superior point on the condyle (Riolo et al., 1974).

**Hinge axis (HA) or condyle**: Centre of the condylar head determined by inspection (Blaseio, 1986). Kohn (1978) defined the point condyle as the centre of the head of the condyloid process.

**Articulare (Ar)**: the point at the junction of the contour of the external cranial base and the dorsal contour of the condylar processes projected in the midsagittal plane (Wei, 1965; Brown, 1973).

**Gonion (Go)**: a point on the bony contour of the angle of the mandible located by bisecting the angle formed by the line tangent to the lower border and a line through articulare and the posterior border of the ramus (Lande, 1952; Nanda, 1955; Wei, 1965).

**Menton (Me)**: the most inferior point on the symphyseal outline (Riolo et al., 1974).

**Pogonion (Pg)**: the most anterior point on the contour of the bony chin relative to a perpendicular to SN-7 plane (Riolo et al., 1974).

**Down's B point or supramentale (B)**: the deepest point in the midsagittal plane between infradentale and pogonion, usually anterior to and slightly below the apices of the mandibular incisors (Burstone, 1978). According to Moyers B point cannot be determined if the chin profile is flat.

**Lower incisal apex (AI)**: the root tip of the mandibular central incisor (Riolo et al., 1974).

**Lower incisal edge (IS)**: the incisal tip of the mandibular central incisor (Riolo et al., 1974).

**Upper incisal edge (IS)**: the incisal tip of the maxillary central incisor (Riolo et al., 1974).

**Upper incisal apex (AS)**: the root tip of the maxillary central incisor (Riolo et al., 1974).

**Down's A point or subspinale (A)**: the deepest point in the midsagittal plane between the anterior nasal spine and supradentale, usually around the level of and anterior to the apex of the maxillary central incisors (Burstone, 1978).

**Anterior nasal spine or acanthion (ANS)**: the tip of the median sharp bony process of the maxilla at the lower margin of the anterior nasal opening (Riolo et al., 1974).

**Posterior nasal spine (PNS)**: the most posterior point at the sagittal plane on the bony hard palate (Riolo et al., 1974).

**Upper molar crown (MS)**: the distal contact (height of contour) of the maxillary first molar relative to the occlusal plane (Riolo et al., 1974).

**Lower molar crown (MI)**: the distal contact (height of contour) of the mandibular first molar relative to the occlusal plane (Riolo et al., 1974).

### 5.4.2. *Cephalometric lines (Figure 5.3)*

**Nasion-sella line (NSL)**: a line passing through nasion and sella (Solow, 1966).

**Sella-nasion-7 (SN-7)**: a line constructed by drawing a line 7° to SN plane with its origin at sella as described by Marcotte (1981). Burstone (1978) refers to SN-7 line as a surrogate Frankfort plane with its origin at nasion.

**Frankfort horizontal (FH)**: the line passing through porion and orbitale (Scott, 1967).

**Mandibular line or plane (ML)**: a line drawn through menton and gonion. This line has also been defined as the tangent to the lower border of the mandible or a line joining gonion and gnathion (Salzmann, 1960).

**Functional occlusal line (FOL)**: a line averaging the points of posterior occlusal contact from the first permanent molars to the first premolars (Moyers, 1987).

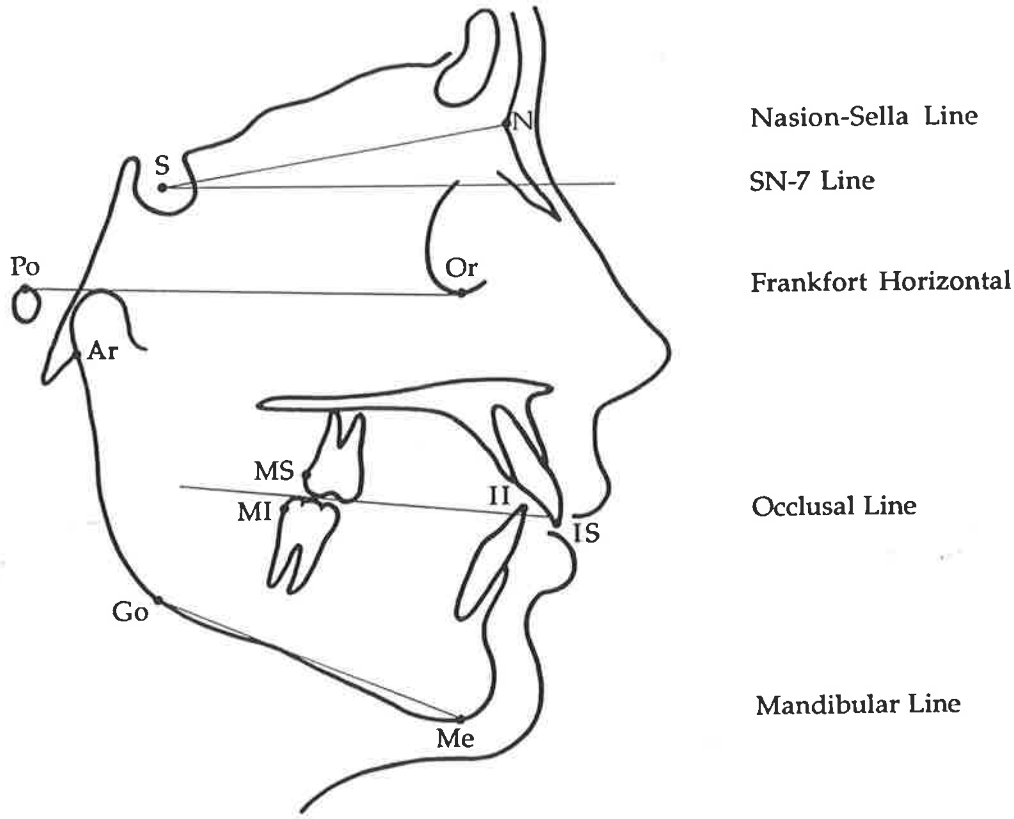



**Figure 5.3 : Reference lines referred to in the text**

### *5.5. CALCULATION OF LINEAR AND ANGULAR VARIABLES*

The variables were selected from those reported by Kohn (1978) and Lake et al. (1981). A second program by Brown (1986, personal communication), *New Scorer*, was used to compute all measurements. A menu within the program allows a variety of combinations between any of the digitised points. Nine linear and seven angular variables (Figure 5.4) were calculated from the digitised points and stored as disk files. The files were transferred from an *Apple IIGS* computer to an *Apple Macintosh SE* computer via *Mac Transfer 1.01 (Southeastern Software, 1984)* for final editing and statistical evaluation.

#### *5.5.1. Linear and angular variables (Figure 5.4)*

**Posterior facial height (PFH)**: the distance between gonion and sella perpendicular to the SN-7 line.

**Anterior facial height (AFH)**: The distance between menton and nasion perpendicular to the SN-7 line.

**Mandibular plane angle (SNGoMe)**: The angle formed between nasion-sella line and the mandibular line.

**SNB**: the angle formed between nasion-sella line and a line drawn through nasion and Down's B point.

**Gonial angle (ArGoMe)**: the angle formed by a line tangent to the mandibular ramus and the mandibular plane.

**Gonial arc radius (HA-Go)**: the distance between condylion and gonion.

**Ramal angle (SNArGo)**: the angle formed between nasion-sella line and the line Ar-Go.

**B point horizontal (B x)**: the distance between Down's B point and a line drawn perpendicular to nasion-sella line.

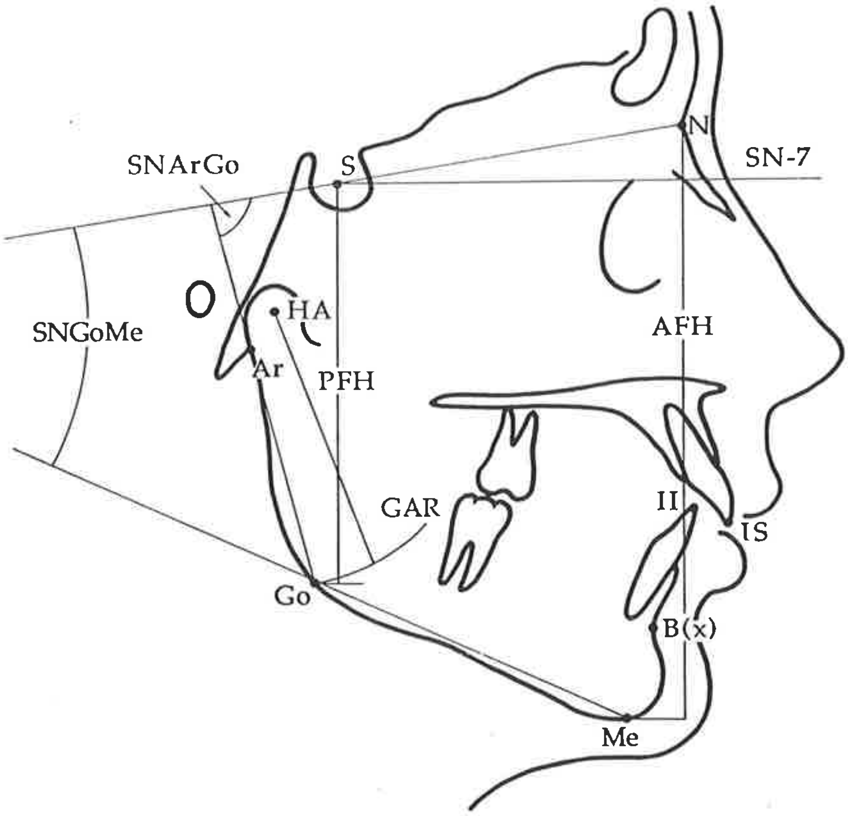
**Upper incisor angle (Mx1-SN)**: the angle between NSL and a line drawn through IS and AS.

**Interincisal angle (IIA):** the angle between the line IS-AS and the line II-AI.

**Lower incisor angle (IMPA)**: the angle between the mandibular line and the line II-AI.

**Overjet (OJ)**: the distance between IS and II measured parallel to the occlusal plane.

**Overbite (OB)**: the distance between IS and II measured perpendicular to the occlusal plane.




| Angular variables | | | Linear variables | | |
|---|---|---|---|---|---|
| 1 | SNArGo | Ramal angle | 1 | AFH | Anterior facial height |
| 2 | SNGoMe | Mandibular plane angle | 2 | PFH | Posterior facial height |
| 3 | ArGoMe | Gonial angle | 3 | GAR | Gonial arc radius |
| 4 | SNB | | 4 | B(x) | B point (horizontal) |
| | | | 5 | Overjet | |
| | | | 6 | Overbite | |

**Figure 5.4 : Angular and linear variables used to evaluate dentoskeletal changes following bilateral sagittal split advancement.**

### 5.6. STATISTICAL ANALYSIS

Each variable within the four groups was assessed by the mean value, standard error and minimum and maximum value using *Statview SE 1.03 (Abacus Concepts Inc., 1988)*. The differences between each period (T1 to T5) for the sixteen variables were calculated by *Statview SE*. The Student's *t*-test for paired and unpaired values was used to determine the significance of differences for each variable (Table 5.4).

Pearson's product-moment correlations (*r*) were calculated for the screw and wire fixation groups (Table 5.4). An *r* value greater than 0.6 was designated a high correlation, between 0.4 and 0.6 moderate and less than 0.4 low.

**Table 5.4. Statistical analysis**

| | | |
|---|---|---|
| $\bar{x}$ | Mean | $\frac{\Sigma x}{N}$ |
| se | Standard error of the mean | $\frac{s}{\sqrt{N}}$ |
| *r* | Correlation coefficient | $\frac{\Sigma(x-\bar{x})(y-\bar{y})}{\sqrt{\Sigma(x-\bar{x})^2(y-\bar{y})^2}}$ |
| *t* | Student's unpaired *t*-test | |

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\dfrac{\left[\Sigma(x_1)^2 - \dfrac{(\Sigma x_1)^2}{N_1}\right] + \left[\Sigma(x_2)^2 - \dfrac{(\Sigma x_2)^2}{N_2}\right]}{N_1+N_2-2} * \left[\dfrac{N_1+N_2}{N_1 N_2}\right]}}$$

where
- N = number of determinations
- s = standard deviation
- x,y = observed scores
- $\bar{x}_1$ = mean of the group 1 observations
- $\bar{x}_2$ = mean of the group 2 observations

# CHAPTER 6

# MATERIALS AND METHODS
# ERRORS OF THE METHOD

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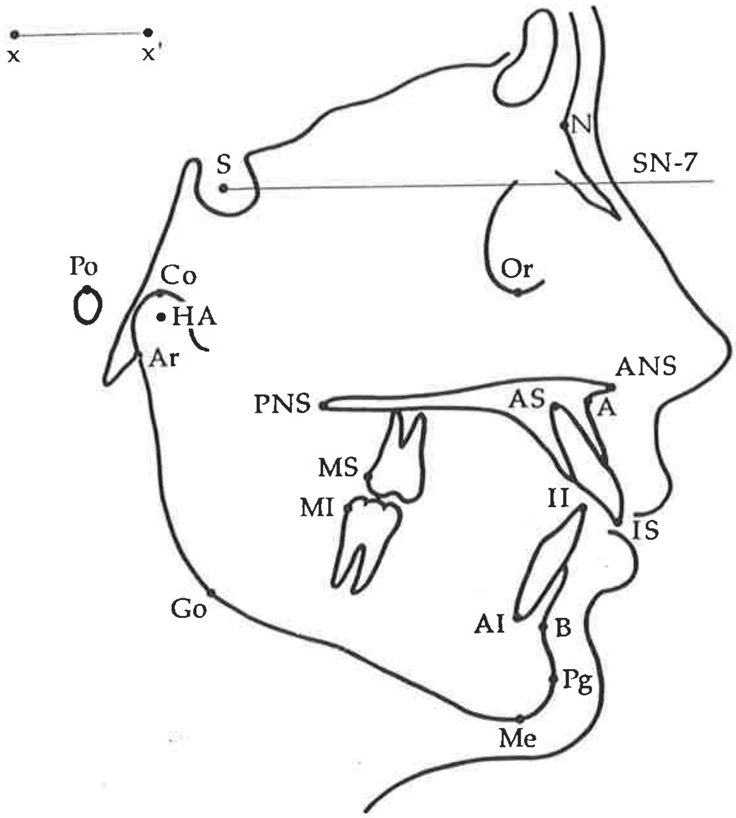
## *6.1. MATERIALS AND METHODS*

To establish the validity of results in this study, an assessment of the magnitude of cephalometric errors was necessary. The magnitude of error associated with tracing, superimposition and digitising was assessed by a series of double determinations for 10 cephalograms. from 3 cases. These were randomly selected from the radiographic files of the Oral and Maxillofacial Surgery Unit, The University of Adelaide.

Repeat tracing, superimposition and digitising were separated by one week and re-recorded by one observer. Tracings were orientated to the SN-7 line on the digitiser tablet and secured with cellulose tape. Alphanumeric data relating patient details and magnification compensation were entered. Magnification of 8.8% (Farrer, 1984) was not corrected. Twenty hard tissue points (Figure 6.1) and 2 fiducial points (x and x′) were digitised on a *Hewlett Packard* 9874A digitiser configured to an *Apple IIe* computer. Each nominated point was centrally aligned in the large window cross-hair cursor and registered by depressing a perimeter button. Data was transformed automatically by the computer and saved to disk for editing. The cephalometric software program developed by Professor Tasman Brown, The University of Adelaide, computes transformations of the cartesian coordinates relative to a nominated reference line. The line formed by x—x′ served as the line of reference. The computer was also programmed to perform superimpositions using the first fiducial point (x) as the point of registration. Error associated with the digitising equipment has been critically assessed by Farrer (1984). The total error from the Hewlett Packard digitiser was ± 0.01 mm under normal operating conditions.




| | | | | | |
|---|---|---|---|---|---|
| 1 | x | Fiducial point 1 | 12 | Pg | Pogonion |
| 2 | x' | Fiducial point 2 | 13 | B | Down's B point |
| 3 | N | Nasion | 14 | AI | Lower incisal apex |
| 4 | S | Sella | 15 | II | Lower incisal tip |
| 5 | Po | Porion | 16 | IS | Upper incisal tip |
| 6 | Or | Orbitale | 17 | AS | Upper incisal apex |
| 7 | Co | Condylion | 18 | A | Down's A point |
| 8 | HA | Hinge axis | 19 | ANS | Anterior nasal spine |
| 9 | Ar | Articulare | 20 | PNS | Posterior nasal spine |
| 10 | Go | Gonion | 21 | MS | Upper molar crown |
| 11 | Me | Menton | 22 | MI | Lower molar crown |

**Figure 6.1 : Hard tissue points listed in order of digitising sequence**

Scattergrams were produced to illustrate the reproducibility of each point using the method described by Broch et al. (1981). The first reading for each point was arbitrarily assigned as origin. The individual points on the scattergram represented the difference between the first and second cephalogram indicating the dispersion of the location errors.

To establish the total error for angular and linear measurement, a modification of the method described by Will et al. (1984) was used. Ten films were traced, superimposed and digitised on 4 occasions giving 20 double determinations. Measurements for the nine angular variables and four linear variables were calculated by the computer.

To assess whether differences could be demonstrated between computer-determined and manual mensuration, nine angular variables and four linear variables were compared by Student's *t*-test for paired values. Fifty randomly selected radiographs were individually placed over a fluorescent light box and traced on *Ortho Trace*™ 0.08 mm matte acetate sheet with a sharp HB lead pencil. Thirteen cephalometric points were identified with a pencil point prior to measurement. Linear and angular measurements were made with a *Unitek*™ *Baum* cephalometric protractor (1° or 1 mm graduations). Each acetate tracing was hand measured on two separate occasions and then digitised. The mean of the two manual measurements was compared against the computer-derived measurements.

The accuracy of the computer measurement was established beforehand by comparing a small series of angles and distances against another computer system (*Apple* ® Macintosh SE and *Scriptel*™ 1212 digitiser). Variation did not exceed 0.02°/mm.

*6.2. STATISTICAL ANALYSIS*

The differences between the first and second determination were expressed as the mean difference ($M_{diff}$), the standard error of the mean difference $E(M_{diff})$, the standard deviation of a single determination (S error) and the percentage of the observed variance attributable to errors following the procedure of Dahlberg (1940). The Student's t-test for paired values was used to assess whether the differences differed significantly from zero at the 5% (t = 2.262) and 1% (t = 3.250) levels for 9 degrees of freedom. Table 6.1 lists the respective formulae.

**Table 6.1. Statistical analysis of the experimental error**

| | | |
|---|---|---|
| $M_{diff}$ | Mean difference between two determinations | $\frac{\Sigma \text{diff}}{N}$ |
| $E(M_{diff})$ | Standard error of the mean difference | $\frac{S_{diff}}{\sqrt{N}}$ |
| S (error) | Standard deviation of a single determination (Dahlberg, 1940) | $\sqrt{\frac{\Sigma \text{diff}^2}{2N}}$ |
| % E var. | Error variance per cent | $\frac{S(\text{error})^2 \times 100}{S^2}$ |
| *t* value | Student's paired *t* -test | $\frac{M_{diff}}{E(M_{diff})}$ |

where
diff = difference between two determinations
N = number of double determinations
2N = number of single determinations
$S^2$ = observed variance of the measurement

# IV

# Results

# CHAPTER 7

# RESULTS

# EARLY, INTERMEDIATE AND LONG TERM DENTOSKELETAL EFFECTS FOLLOWING SAGITTAL SPLIT ADVANCEMENT

## *7.1.. INTRODUCTION*

The results for each variable are tabulated by the method of fixation and grouped by sex. The results are presented in "Section 7.2: Analysis of variables by group." Analysis of the data by Student's *t*-test revealed that there were no statistically significant sex differences within any of the groups. In addition, no statistical differences were shown between groups 1 and 2, nor between groups 3 and 4. Therefore, the screw fixation and the wire fixation subgroups were combined. The results are presented in "Chapter 8: Analysis of variables by method of fixation." Correlations relating the relevant variables to relapse are presented in Chapter 9.

## Section 7.2.

## ANALYSIS OF VARIABLES BY GROUP

### *7.2.1. MANDIBULAR MOVEMENT*

#### *7.2.1.1. **Horizontal advancement and relapse** (Tables 7.1 & 7.2)*

The results for the screw fixation groups and the wire fixation groups are summarised in Table 7.1 and 7.2 respectively.

<u>*Group 1: BSSA screws*</u> *(N = 10; Table 7.1)*

The mean mandibular advancement at B point was 4.0 ± 0.40 mm with a range of 2.7 to 6.3 mm. At T3, a mean decrease of -0.8 mm was measured but this was not statistically significant. A further loss of -1.3 mm (R: -4.3 - 0.8 mm; $P < 0.05$) occurred after 12 months representing a loss of -52.5% (R: -2.5 to -112%) of the initial advancement.

The three males had a mean increase of 4.8 mm at surgery and had lost statistically insignificant amounts at T3 and T4. The loss of -1.6 mm after 12 months was equivalent to a mean relapse of -33.3% but was not statistically significant. The seven females were advanced a mean 3.7 mm and lost statistically significant ($P < 0.05$) amounts at T3 (-0.9 mm) and T4 (-1.3 mm). This gave a mean percentage relapse of -59.4% at twelve months which was statistically significant ($P < 0.05$).

Two cases were followed to T5, one male 17.3 years and one female 22.3 years. The male subject was advanced 6.3 mm and lost -1.1 mm (-17.5%) over 2 years. Most of the relapse (-15.9%) was measured at T3. No significant change was noted between T4 and T5. The female patient underwent total relapse despite a slightly smaller advancement (5.2 mm). Almost half of the relapse (-48%) occurred in the first 6 weeks and the remainder occurred over the next eleven months. No significant loss occurred between T4 and T5.

*Group 2: BSSA & LFI screws* (*N* = 8; *Table 7.1*)

Mandibular advancement ranged from 4.3 to 10.3 mm giving a mean advancement of 7.1 mm. A mean loss of -1.7 mm ($P < 0.05$) occurred by T3 with no significant loss at T4. The relapse at T4 as a percentage of the initial advancement was -29.5% (R:-14.1 to -67.2%). None of the differences between sexes for percentage relapse were statistically significant.

**Table 7.1: Horizontal advancement (T1-T2) and relapse pattern (T2-T5) for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 3** | **F: 7** | **Total: 10** | **M: 1** | **F: 7** | **Total: 8** |
| **T1-T2** (± se mm) | 4.8 | 3.7 | 4.0 ± 0.40 | 8.4 | 7.0 | 7.1 ± 0.74 |
| *t*-value | 4.55* | 11.08** | 10.10** | | 8.42** | 9.68** |
| Min. (mm) | 2.8 | 2.7 | 2.7 | | 4.3 | 4.3 |
| Max. (mm) | 6.3 | 5.2 | 6.3 | | 10.3 | 10.3 |
| **T2-T3** (± se mm) | -0.3 | -0.9 | -0.8 ± 0.62 | -2.6 | -1.5 | -1.7 ± 0.64 |
| *t*-value | 0.15 | 2.55* | 1.21 | | 1.98 | 2.53* |
| Min. (mm) | -3.8 | -2.5 | -3.8 | | -4.3 | -4.3 |
| Max. (mm) | 3.7 | 0.6 | 3.7 | | 1.0 | 1.0 |
| **% relapse (T2-T3)** | -6.3 | -24.3 | -20.0 | -31.0 | -21.4 | -23.9 |
| **T3-T4** (± se mm) | -1.3 | -1.3 | -1.3 ± 0.52 | 0.0 | -0.5 | -0.4 ± 0.36 |
| *t*-value | 0.82 | 2.68* | 2.49* | | 0.76 | 0.76 |
| Min. | -4.3 | -3.3 | -4.3 | | -2.2 | -2.2 |
| Max. | 0.8 | 0.1 | 0.8 | | 1.0 | 1.0 |
| **% relapse (T2-4)** | -33.0 | -59.4* | -52.5* | -31.0 | -28.6* | -29.5** |
| Min. (%) | -2.5 | -12.1 | -2.5 | | -14.1 | -14.1 |
| Max. (%) | -74.7 | -111.8 | -111.8 | | -67.2 | -67.2 |
| **Long-term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se mm) | +6.3 | +5.2 | +5.8 ± 0.56 | +8.4 | +5.8 | +7.1 ± 1.28 |
| **T2-T3** | -1.0 | -2.5 | -1.7 ± 0.77 | -2.6 | -0.6 | -1.6 ± 1.00 |
| **T3-T4** | +0.8 | -3.3 | -1.3 ± 2.05 | 0.0 | -0.2 | -0.1 ± 0.10 |
| **T4-T5** | -1.0 | -0.7 | -0.8 ± 0.13 | +0.5 | +1.0 | +0.8 ± 0.27 |
| **% relapse (T2-5)** | -17.8 | -125.0 | -58.9 | -25.0 | +4.0 | -10.5 |

Group 1: BSSA SF: Bilateral sagittal split advancement with screw fixation. Degrees of freedom = 9 for T2-T4.
Group 2: LFI & BSSA SF: Bilateral sagittal split advancement and Le Fort I osteotomy with screw fixation. Degrees of freedom = 7 for T2-T4.
* = $P < 0.05$
** = $P < 0.005$

There was one T5 case from each sex. The female patient, aged 23.0 years, did not show long term (T5) relapse following advancement of 5.8 mm, however, clinically insignificant losses occurred at T3 and T4. In the male, aged 18.2 years, relapse of -31.0% (-2.6 mm) was measured after an advancement of 8.4 mm. All of the measurable relapse occurred in the first 6 weeks. Insignificant changes occurred between T3 and T5.

<u>Group 3: BSSA wire</u> *(N = 12; Table 7.2)*

The mandible was advanced a mean 5.9 ± 0.63 mm (R: 1.5 - 9.5 mm). Early relapse of -29% (-1.5 mm; $P < 0.001$) was noted by T3. The mandible relapsed further between T3-T4 (-0.6 mm) but this change was not statistically significant. The relapse at T4 averaged -35.6% with a range of -66.7% to +11.2%. Although males averaged less relapse than females (-21.3% vs -48.3%), the difference was not statistically significant.

Nine of the twelve patients were reviewed at T5 (mean: 2.5 years; R: 1.9 - 4.0). Three males aged between 16.3 and 21.8 years (mean: 18.6) were advanced a mean distance of 5.4 mm. Initial relapse of -25.9% (-1.4 mm; T2-T3) was followed by statistically insignificant gains during T4 (+1.8%) and T5 (+16.7%). Thus by T5, a loss of -7.0% had occurred over the initial advancement.

The six females aged from 13 to 22.1 (mean: 16.2 years) recorded a T3 relapse of -25.9% (-1.5 mm) after 5.8 mm advancement. There was further relapse of -20.7% at T4 and at T5 (1.7%). A net relapse of -48.2% was measured at T5.

This sex difference in relapse percentage at T4 (-48.3 F vs -21.3 M; $P = 0.243$) and T5 (-48.2 F vs -7.0 M; $P = 0.132$) was not statistically significant when tested by the Student's *t*-test for unpaired values.

<u>Group 4: BSSA & LFI wire</u> *(N = 10; Table 7.2)*

Ten patients averaged mandibular advancement of 5.7 ± 1.10 mm (R: 0.8 -14.9 mm). No significant mean changes occurred at T3 (0.1 mm) or

T4 (-1.0 mm) for this group of patients. The mean percentage relapse was -15.8% with a wide range of variation (-62.3 - +83.1%). Male patients displayed positive movement 12 months post-surgery most probably associated with growth. The greatest relapse in this group was -12.3%. The male patient with the largest postoperative gain, had a B point shift of 1.5 mm between T2-T3 and T3-T4. By comparison, female relapse ranged from -62.3% to a positive gain of 19.5%. However, none of the differences between sexes for percentage relapse were statistically significant.

**Table 7.2: Horizontal advancement (T1-T2) and relapse pattern (T2-T5) for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 4** | **F: 8** | **Total: 12** | **M: 3** | **F: 7** | **Total: 10** |
| **T1-T2** (± se mm) | 6.1 | 5.8 | 5.9 ± 0.63 | 3.9 | 6.1 | 5.7 ± 1.10 |
| *t*-value | 5.68** | 6.95** | 6.88** | 2.49 | 4.49** | 5.21** |
| Min. (mm) | 3.6 | 1.5 | 1.5 | 0.8 | 2.5 | 0.8 |
| Max. (mm) | 8.5 | 9.5 | 9.5 | 5.9 | 14.9 | 14.9 |
| **T2-T3** (± se mm) | -1.5 | -1.7 | -1.5 ± 0.24 | 0.9 | -0.2 | 0.1 ± 0.62 |
| *t*-value | 3.5* | 5.81** | 6.88** | 0.03 | 0.28 | 0.19 |
| Min. (mm) | -2.6 | -3.0 | -3.0 | 0.0 | -2.9 | -2.9 |
| Max. (mm) | -0.2 | -0.6 | -0.2 | 2.7 | 2.9 | 2.9 |
| **% relapse (T2-T3)** | -24.6 | -29.3 | -25.4 | +23.1 | -3.3 | +1.8 |
| **T3-T4** (± se mm) | +0.2 | -1.1 | -0.6 ± 0.39 | +0.4 | -1.5 | -1.0 ± 0.76 |
| *t*-value | 0.24 | 2.06 | 1.78 | 0.36 | 1.66 | 1.34 |
| Min. | -0.6 | -2.9 | -2.9 | -0.7 | -3.8 | -3.8 |
| Max. | 0.6 | 1.1 | 1.1 | 1.5 | 2.7 | 2.7 |
| **% relapse (T2-4)** | -21.3 | -48.3 | -35.6 | +35.1 | -27.9 | -15.8 |
| Min. (%) | +11.2 | +10.5 | +11.2 | +83.1 | +19.5 | +83.1 |
| Max. (%) | -36.3 | -66.7 | -66.7 | -12.3 | -62.3 | -62.3 |
| **Long-term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se mm) | +5.4 | +5.8 | +5.6 ± 0.82 | +5.9 | +5.1 | +5.2 ± 0.82 |
| **T2-T3** | -1.4 | -1.5 | -1.5 ± 0.28 | 0.0 | +0.7 | 0.6 ± 0.76 |
| **T3-T4** | +0.1 | -1.2 | -1.1 ± 0.44 | -0.7 | -2.0 | -1.7 ± 0.28 |
| **T4-T5** | +0.9 | -0.1 | +0.3 ± 0.32 | +1.4 | -0.4 | -0.1 ± 0.40 |
| **% relapse (T2-5)** | -7.0 | -48.2 | -41.1 | +11.8 | -33.3 | -23.1 |
| Min. (%) | +36.3 | +24.3 | +36.3 | | +3.9 | +11.8 |
| Max. (%) | -35.2 | -89.6 | -89.6 | | -104.9 | -104.9 |

Group 3: BSSA WF: Bilateral sagittal split advancement with wire fixation. Degrees of freedom = 11 for T2-T4.
Group 4: LFI & BSSA WF: Bilateral sagittal split advancement and Le Fort I osteotomy with wire fixation. Degrees of freedom = 9 for T2-T4.
* = $P < 0.05$
** = $P < 0.005$

Seven patients (6 females and 1 male) who satisfied T5 criteria had long term relapse of -23.1% with -21.2% occurring in the first year. Marked individual variation was observed in the female sample. One female relapsed 105%, however, the initial advancement was only 2.9 mm. More than half of the relapse (59%) occurred in the first year. The male patient relapsed 12% in the first 12 months but this was totally compensated for after a further 12 months (T5).

#### 7.2.1.2. *Angle SNB*

<u>*Group 1: BSSA screws*</u> *(N = 10; Table 7.3)*

The SNB angle increased a mean 2.8 ± 0.24° at T2 with a range of 1.7° to 4.1°. This angle changed minimally thereafter giving a net increase of 1.5 ± 0.29° over the initial value.

The male subjects increased a mean of 3.0 and lost 1.0° over the next 12 months. The females gained 2.6° at surgery and lost 1.4° after one year.

The two long term cases both had initial increases in SNB angle following surgery. The male subject increased 7.8° at T2 and decreased -1.0° at T3, -1.1° at T4 and T5 (-0.9°). This gave a net increase of 4.9° after 24 months. The female patient increased 9.5° at surgery and decreased -2.6° at T3. Small changes at T4 (-0.2°) and T5 (-0.4°) gave a net increase of 6.4° at two years.

<u>*Group 2: BSSA & LFI screws*</u> *(N = 8; Table 7.3)*

The angle SNB showed a mean increase of 4.3 ± 0.33° (R: 3.1 - 5.5°). Mean changes of -1.1° at T3 and T4 (-0.3°) gave a net change of 2.7 ± 0.27° after 12 months. The six females recorded a surgical increase of 4.3° which decreased at T3 (-1.0°) and T4(-0.4°). The net change was an increase of 2.6° at T4 with a range from 2.1° to 4.4°. None of the changes after the initial surgical change were statistically significant.

The long term female patient increased 3.4° at surgery and at 6 weeks decreased -0.7°. There was no change at T4 and only a small change at T5 (0.5°) leaving a net gain of 3.3° two years after surgery. In the male, an increase of 4.4° was measured at T2 whilst a small loss occurred at T3 (-1.3°). A minor change at T5 (0.4°) resulted in a net gain of 3.5°.

**Table 7.3: Changes in the angle SNB for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 3** | **F: 7** | **Total: 10** | **M: 1** | **F: 7** | **Total: 8** |
| **T1-T2** (± se deg) | 3.0 | 2.6 | 2.8 ± 0.24 | 4.4 | 4.3 | 4.3 ± 0.33 |
| *t*-value | 3.63 | 4.46 | 5.96** | | 1.84 | 2.25 |
| Min. (deg) | 1.7 | 2.0 | 1.7 | | 3.1 | 3.1 |
| Max. (deg) | 4.1 | 3.7 | 4.1 | | 5.5 | 5.5 |
| **T2-T3** (± se deg) | -0.1 | -0.7 | -0.5 ± 0.37 | -1.3 | -1.0 | -1.1 ± 0.35 |
| *t*-value | 0.41 | 0.50 | 0.64 | | 1.98 | 0.59 |
| Min. | -1.8 | -1.8 | -1.8 | | -2.8 | -2.8 |
| Max. | 2.3 | 0.3 | 2.3 | | 0.1 | 0.1 |
| **T3-T4** (± se deg) | -0.9 | -0.7 | -0.8 ± 0.27 | 0.0 | -0.3 | -0.3 ± 0.23 |
| *t*-value | 3.08 | 1.44 | 0.03 | | 0.19 | 0.37 |
| Min. | -2.7 | -1.7 | -2.7 | | -1.2 | -1.2 |
| Max. | 0.2 | -0.2 | 0.2 | | 0.3 | 0.3 |
| **T1-T4**** (± se deg) | 2.0 | 1.2 | 1.5 ± 0.29 | 3.1 | 2.6 | 2.7 ± 0.27 |
| Min. | 1.3 | 0.3 | 0.3 | | 2.1 | 2.1 |
| Max. | 3.5 | 2.0 | 3.5 | | 4.4 | 4.4 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se deg) | 7.8 | 9.5 | 8.7 ± 0.86 | 4.4 | 3.4 | 3.9 ± 0.48 |
| **T2-T3** | -1.0 | -2.6 | -1.8 ± 0.77 | -1.3 | -0.7 | -1.0 ± 0.32 |
| **T3-T4** | -1.1 | -0.2 | -0.6 ± 0.44 | 0.0 | 0.0 | 0.0 ± 0.02 |
| **T4-T5** | -0.9 | -0.4 | -0.8 ± 0.52 | 0.4 | 0.5 | 0.5 ± 0.03 |
| **T1-T5** | 4.9 | 6.4 | 8.2 ± 1.35 | 3.5 | 3.3 | 3.4 ± 0.12 |
| Min. | 1.3 | 0.3 | 0.3 | | 2.1 | 2.1 |
| Max. | 3.5 | 2.0 | 3.5 | | 4.4 | 4.4 |

* = $P < 0.05$
** = $P < 0.005$

*Group 3: BSSA wire (N = 12; Table 7.4)*

The angle SNB averaged an increase of 3.8 ± 0.37° with surgery. A highly significant decrease of -0.9° occurred at T3. The decrease of -0.7° at T4 was not significant. The net effect at 12 months was a gain of 2.4 ± 0.27°. The eight females in the group averaged changes of 4.0° at T2, -1.0° at T3 ($P < 0.005$) and -0.9° at T4 ($P < 0.05$) resulting in a net gain of 2.3 ± 0.34°. An average net gain of 2.7 ± 0.26° was recorded for the four males. A significant loss of -0.7° during T2-T3 was measured. None of the differences between sexes were significant. The nine long term patients underwent minor postsurgical changes providing a long term increase of 2.5 ± 0.41° (R: 0.9 - 4.4°).

**Table 7.4: Changes in the angle SNB for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 4** | **F: 8** | **Total: 12** | **M: 3** | **F: 7** | **Total: 10** |
| **T1-T2** (± se deg) | 3.7 | 4.0 | 3.8 ± 0.37 | 3.8 | 4.0 | 3.9 ± 0.58 |
| *t*-value | 4.79** | 8.83** | 10.33** | 12.50* | 4.82* | 6.84** |
| Min. (deg) | 2.5 | 2.2 | 2.2 | 3.4 | 2.0 | 2.0 |
| Max. (deg) | 5.9 | 5.9 | 5.9 | 4.4 | 7.6 | 7.6 |
| **T2-T3** (± se deg) | -0.7 | -1.0 | -0.9 ± 0.14 | -0.4 | -0.2 | -0.3 ± 0.42 |
| *t*-value | 3.6* | 5.42** | 6.4** | 0.37 | 0.49 | 0.65 |
| Min. | -1.2 | -1.6 | -1.6 | -2.1 | -1.3 | -2.1 |
| Max. | -0.3 | -0.4 | -0.4 | 1.4 | 0.1 | 1.4 |
| **T3-T4** (± se deg) | -0.3 | -0.9 | -0.7 ± 0.22 | 0.4 | -1.4 | -0.7 ± 0.41 |
| *t*-value | 1.62 | 2.89* | 3.08* | 0.79 | 5.37* | 1.77 |
| Min. | -0.8 | -2.2 | -2.2 | -0.4 | -2.3 | -2.3 |
| Max. | 0.0 | 0.1 | 0.1 | 1.4 | -0.8 | 1.4 |
| **T1-T4**** (± se deg) | 2.7 | 2.3 | 2.4 ± 0.27 | 3.9 | 2.7 | 3.0 ± 0.57 |
| Min. | 1.8 | 1.3 | 1.3 | 2.7 | 0.8 | 0.8 |
| Max. | 3.9 | 4.1 | 4.1 | 5.1 | 6.2 | 6.2 |
| **Long term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se deg) | 3.8 | 4.0 | 4.0 ± 0.45 | 3.6 | 3.4 | 3.4 ± 0.58 |
| **T2-T3** | -0.7 | -1.0 | -0.9 ± 0.14 | -0.5 | 0.1 | -0.1 ± 0.34 |
| **T3-T4** | -0.4 | -1.2 | -0.9 ± 0.24 | -0.4 | -1.2 | -1.0 ± 0.21 |
| **T4-T5** | 0.5 | 0.0 | 0.2 ± 0.17 | 0.7 | -0.2 | -0.1 ± 0.18 |
| **T1-T5*** | 3.2 | 2.2 | 2.5 ± 0.41 | 3.4 | 2.3 | 2.5 ± 0.78 |
| Min. | 2.7 | 0.9 | 0.9 | | 0.5 | 0.5 |
| Max. | 3.9 | 4.4 | 4.4 | | 6.2 | 6.2 |

* = $P < 0.05$
** = $P < 0.005$

*Group 4: BSSA & LFI wire (N = 10; Table 7.4)*

The angle SNB increased 3.9 ± 0.58° at surgery and then decreased at T3 (-0.3 ± 0.42°) and T4 (-0.7 ± 0.41°). This resulted in a net gain of 3.0 ± 0.57°. The seven females in this group initially increased 4.0° at operation and decreased minimally at T3 (-0.2°). A statistically significant loss ( 05) at T4 (-1.4°) gave a residual increase of 2.7 ± 0.74°. A significant sex difference was found at T3-T4 ($P < 0.05$). The 3 males had a mean increase of 0.4 ± 0.54° and the females had a statistically significant ($P < 0.05$) decrease of -1.4 ± 0.26°. In the long term, the seven patients lost a mean -0.2° so that the net change (T1-T5) after 2 years was 2.5 ± 0.78° (R: 0.5 - 6.2°).

### 7.2.2. *PROXIMAL AND DISTAL SEGMENT ALTERATION*

#### 7.2.2.1. *Condylar displacement (HA-Go)*

*Group 1: BSSA screws (N = 10; Table 7.5)*

Gonial arc radius increased an average of 1.0 ± 0.39 mm following surgery and had decreased by a similar amount when reviewed at six weeks (-1.0 ± 0.66 mm). The mean change in gonial arc for the period T3-T4 (0.3 ± 0.61 mm) was minimal. For the male group, the mean of the gonial arc radius did not alter between T1-T2. Small fluctuations between T3 and T4 were measured on average but individual variation was apparent. There was significant ($P < 0.05$) distraction of the condyle in the female group but gonial arc radius had resumed its presurgical length by T3. For the two long term cases, gonial arc radius increased slightly at surgery for the male (0.7 mm) but quite markedly in the female (2.6 mm). Condylar seating had occurred by T3 but there were unexpected T4-T5 changes. A decrease of -2.0 mm in the female patient and -0.9 mm in the male was measured.

*Group 2: BSSA & LFI screws (N = 8; Table 7.1)*

A mean increase in gonial arc radius of 1.6 ± 0.89 mm was measured in this group. A return of the proximal segment occurred by T3 (-1.2 ± 0.64 mm) with minimal change at T4 (0.5 ± 0.90 mm). The female patients averaged an increase in radius of 2.2 mm (R: -0.3 - 5.0 mm). Some return had occurred at T3 but there appeared to be continued distraction in individuals at T4.

In the long term male, an apparent posterosuperior positioning of the condyle was noted at T2. No change occurred over the next six weeks and there was a slight increase in gonial arc radius at T4 (0.9 mm). The radius had increased 1.3 mm when reviewed at T5. The female patient had an increase in gonial arc radius 1.5 mm at surgery which decreased at T3 (-2.3 mm). An increase of 3.5 mm was measured at T4 with a subsequent decrease (-2.5 mm) at T5.

**Table 7.5: Changes in gonial arc radius for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 3** | **F: 7** | **Total: 10** | **M: 1** | **F: 7** | **Total: 8** |
| T1-T2 (± se mm) | 0.0 | 1.5 | 1.0 ± 0.39 | -2.2 | 2.2 | 1.6 ± 0.89 |
| *t*-value | 0.07 | 3.27* | 1.27 | | 2.68* | 0.90 |
| Min. (mm) | -0.9 | -0.3 | -0.9 | | -0.3 | -2.2 |
| Max. (mm) | 0.7 | 2.7 | 2.7 | | 5.1 | 5.1 |
| T2-T3 (± se mm) | 0.7 | -1.7 | -1.0 ± 0.66 | 0.0 | -1.4 | -1.2 ± 0.64 |
| *t*-value | 0.38 | 4.25** | 1.70 | | 1.95 | 1.72 |
| Min. | -1.9 | -3.4 | -3.4 | | -3.3 | -3.3 |
| Max. | 4.3 | -0.5 | 4.3 | | 1.8 | 1.8 |
| T3-T4 (± se mm) | -0.8 | -0.1 | 0.3 ± 0.61 | 0.9 | 0.4 | 0.5 ± 0.90 |
| *t*-value | 0.45 | 0.14 | 0.44 | | 0.37 | 0.54 |
| Min. | -4.1 | -1.7 | -4.1 | | -2.7 | -2.7 |
| Max. | 2.4 | 2.3 | 2.4 | | 3.5 | 3.5 |
| T1-T4** (± se mm) | -0.1 | -0.3 | -0.2 ± 0.50 | -1.3 | 0.6 | -0.4 ± 0.52 |
| Min. | -2.1 | -3.2 | -3.2 | | -0.9 | -1.3 |
| Max. | 1.2 | 2.5 | 2.5 | | 2.8 | 2.8 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se mm) | 0.7 | 2.5 | 1.6 ± 0.91 | -2.2 | 1.5 | -0.3 ± 1.86 |
| **T2-T3** | -1.9 | -3.4 | -2.7 ± 0.75 | 0.0 | -2.3 | -1.1 ± 1.14 |
| **T3-T4** | 2.4 | 0.4 | 1.4 ± 1.01 | 0.9 | 2.8 | 2.2 ± 1.31 |
| **T4-T5** | -0.9 | -2.0 | -1.5 ± 0.53 | 1.3 | -2.5 | -0.6 ± 1.86 |
| **T1-T5** | 0.3 | -2.5 | -1.1 ± 1.37 | 0.0 | 0.3 | 0.1 ± 0.17 |

* = $P < 0.05$
** = $P < 0.005$

*Group 3: BSSA wire (N = 12; Table 7.6)*

Gonial arc radius increased 1.6 ± 0.63 mm following surgery but returned within the six weeks (-1.4 ± 0.80 mm). The female patients showed a larger variation in gonial arc than the male subset. Males showed little variation from the presurgical length whereas the females had a range from 0.0 mm to 5.5 mm. The average change of 2.5 mm at T2 was matched by a return of -2.2 mm at T3. Mean changes between T3-T4 and T4-T5 were small averaging -1.4 ± 0.71 mm and -0.4 ± 0.41 mm respectively for the nine long term patients.

**Table 7.6: Changes in gonial arc radius for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 4** | **F: 8** | **Total: 12** | **M: 3** | **F: 7** | **Total: 10** |
| **T1-T2** (± se mm) | -0.2 | 2.5 | 1.6 ± 0.63 | 2.0 | 0.8 | 1.1 ± 0.56 |
| *t*-value | 0.40 | 3.48* | 2.52* | 1.21 | 1.63 | 2.01 |
| Min. (mm) | -1.4 | 0.0 | -1.4 | -0.5 | -1.0 | -1.0 |
| Max. (mm) | 1.1 | 5.5 | 5.5 | 5.0 | 2.0 | 5.0 |
| **T2-T3** (± se mm) | 0.0 | -2.2 | -1.4 ± 0.80 | -1.8 | -1.9 | -1.9 ± 0.59 |
| *t*-value | 0.02 | 2.32 | 1.78 | 1.16 | 3.83* | 3.13* |
| Min. | -2.9 | -5.9 | -5.9 | -4.8 | -3.8 | -4.8 |
| Max. | 2.2 | 0.7 | 2.2 | -0.5 | -1.1 | -0.5 |
| **T3-T4** (± se mm) | 0.3 | -1.7 | -0.9 ± 0.71 | -0.7 | -0.7 | -0.7 ± 0.53 |
| *t*-value | 0.32 | 1.80 | 1.31 | 0.77 | 1.00 | 1.37 |
| Min. | -2.2 | -5.8 | -5.8 | -2.6 | -3.6 | -3.6 |
| Max. | 2.5 | 0.9 | 2.5 | 0.4 | 0.3 | 0.4 |
| **T1-T4**** (± se mm) | 0.1 | -1.3 | -1.1 ± 0.43 | -0.6 | -1.2 | -2.3 ± 0.37 |
| Min. | -1.3 | -3.6 | -3.6 | -2.7 | -2.8 | -4.3 |
| Max. | 1.4 | 1.2 | 1.4 | 0.7 | 0.5 | -0.3 |
| **Long term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se mm) | -1.0 | 1.5 | 1.5 ± 0.79 | 3.3 | -0.1 | 1.2 ± 0.76 |
| **T2-T3** | 0.2 | -1.9 | -1.0 ± 0.92 | -4.8 | -2.4 | -2.9 ± 0.71* |
| **T3-T4** | -0.3 | -1.3 | -1.4 ± 0.87 | 0.3 | 0.1 | -0.1 ± 0.12 |
| **T4-T5** | 0.8 | -0.5 | -0.4 ± 0.41 | 3.4 | 0.1 | 0.6 ± 0.57 |
| **T1-T5** | 0.4 | -1.1 | -1.1 ± 0.46 | 3.6 | -0.9 | -1.2 ± 0.52 |
| Min. | -0.3 | -2.6 | -3.0 | | -1.9 | -1.9 |
| Max. | 1.9 | 0.1 | 0.3 | | 0.7 | 3.6 |

* = $P < 0.05$
** = $P < 0.005$

<u>*Group 4: BSSA & LFI wire (N = 10; Table 7.6)*</u>

As in the previous groups, gonial arc initially increased (1.1 ± 0.46 mm) and had returned by the next observation (-1.9 ± 0.59 mm). Small changes were seen at T4 (-0.7 mm). The females in this group averaged less change than the males and both had returned by T3. The seven long term patients showed a similar pattern with little variation after T3.

### 7.2.2.2. *Posterior facial height (S-Go)*

*Group 1: BSSA screws (N = 10; Table 7.7)*

Posterior facial height did not increase significantly at surgery with a mean value of 0.5 ± 0.35 mm (R: -1.4 - 2.0 mm). Small losses in posterior facial height were recorded at each postsurgical interval but none reached statistical significance. The overall change between T2-T4 was -1.2 ± 0.48 mm with a range of -3.9 to 0.4 mm. The net change from T1-T4 (-0.8 mm) was not statistically significant. Females showed a slight increase in posterior facial height but this decreased by T3 so that at T4 a small reduction (-0.8 mm) had occurred. Males underwent minimal change for the same period and at 12 months, had a similar reduction of -0.6 mm. No significant difference was shown between sexes.

The two long term individuals showed different responses to surgery. The male did not change in this dimension at surgery but shortened -1.6 mm by T3. A gain of 1.9 mm occurred at T4 followed by a small loss of -0.4 mm at T5. The female patient increased posterior facial height by 2.0 mm at surgery and shortened -3.0 mm during the next six weeks. No change was measured between T3 and T4 but further shortening occurred by T5 (-1.9 mm). The long term change in posterior facial height following surgery was -4.7 mm giving a net shortening of -2.7 mm (T1-T5).

*Group 2: BSSA & LFI screws (N = 8; Table 7.7)*

A mild increase of 0.8 ± 0.84 mm was recorded for this group although the range was quite wide (-2.8 - 3.8 mm). By the next period, a mean loss of -1.0 mm had occurred. In general, there was no alteration from the preoperative height at 12 months. The 7 females showed a small increase at surgery but this returned to the presurgical dimension at T3.

**Table 7.7: Changes in posterior facial height for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 3** | **F: 7** | **Total: 10** | **M: 1** | **F: 7** | **Total: 8** |
| **T1-T2** (± se mm) | -0.6 | 0.9 | 0.5 ± 0.35 | -2.8 | 1.3 | 0.8 ± 0.84 |
| *t*-value | 1.29 | 2.60 | 1.27 | | 1.65 | 0.90 |
| Min. (mm) | -1.4 | -0.4 | -1.4 | | -1.1 | -2.8 |
| Max. (mm) | 0.2 | 2.0 | 2.0 | | 3.8 | 3.8 |
| **T2-T3** (± se mm) | 0.6 | -1.6 | -1.0 ± 0.57 | 0.0 | -1.2 | -1.0 ± 0.60 |
| *t*-value | 0.38 | 4.72** | 1.70 | | 1.78 | 1.72 |
| Min. | -1.6 | -3.1 | -3.1 | | -3.5 | -3.5 |
| Max. | 3.5 | -0.6 | 3.5 | | 1.6 | 1.6 |
| **T3-T4** (± se mm) | -0.6 | -0.1 | -0.2 ± 0.53 | 0.9 | 0.4 | 0.4 ± 0.79 |
| *t*-value | 0.41 | 0.13 | 0.44 | | 0.37 | 0.54 |
| Min. | -3.2 | -1.7 | -3.2 | | -2.9 | -2.9 |
| Max. | 1.9 | 2.3 | 2.3 | | 2.8 | 2.8 |
| **T1-T4** (± se mm) | -0.6 | -0.8 | -0.8 ± 0.43 | -1.9 | -0.1 | -0.3 ± 0.43 |
| Min. | -2.1 | -3.4 | -3.4 | | -1.5 | -1.9 |
| Max. | 0.5 | 1.4 | 1.4 | | 1.3 | 1.3 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se mm) | -0.6 | 2.0 | 0.7 ± 1.29 | -2.8 | 0.0 | -1.4 ± 1.41 |
| **T2-T3** | -1.6 | -3.1 | -2.3 ± 0.73 | 0.0 | -1.6 | -0.8 ± 0.82 |
| **T3-T4** | 1.9 | 0.3 | 1.1 ± 0.83 | 0.9 | 2.8 | 1.8 ± 0.92 |
| **T4-T5** | -0.4 | -1.9 | -1.1 ± 0.76 | -1.1 | -2.2 | -0.5 ± 1.64 |
| **T1-T5** | -0.7 | -2.7 | -1.7 ± 1.03 | -0.8 | -1.0 | -0.9 ± 0.12 |

* = $P < 0.05$
** = $P < 0.005$

The male under long term study shortened -2.8 mm at surgery. Posterior facial height did not change at T3 but increased at T4 (0.9 mm) and T5 (1.1 mm). The net effect was that no change was observed in posterior facial height compared to the preoperative value. The female patient did not alter at surgery but shortened -1.6 mm by T3. There was a lengthening of 2.8 mm by T4 which was subsequently lost at T5 (-2.2 mm). Thus the long term effect was a loss of -1.0 mm.

*Group 3: BSSA wire (N = 12; Table 7.8)*

Posterior facial height increased a mean of 0.8 ± 0.58 mm at surgery for the 12 cases. A mean decrease at T3 (-1.0 ± 0.60 mm) was statistically significant ($P < 0.05$). Posterior facial height continued to shorten at T4 (-0.4 ± 0.68 mm). Thus a net shortening in posterior facial height of -1.7 mm occurred (T1-T4) which was statistically significant ($P < 0.05$). Female patients had a statistically significant ($P < 0.05$) increase in posterior facial height of 1.6 mm at T2. A statistically significant ($P < 0.05$) reduction occurred at T3 (-2.2 mm). The net change resulted in a reduction (-1.3 mm) in posterior facial height. The male patients did not alter significantly during the period of observation.

Nine long term cases showed a mean increase in posterior facial height of 0.7 ± 0.72 mm with a range of -1.9 to 4.7 mm. A mean decrease of -1.1 mm at T3 and at T4 of -1.0 mm was observed. No change occurred between T4-T5 although there was individual variation ranging from -2.5 to 1.2 mm. The change from T2 to T5 was -2.2 ± 0.79 mm giving a net decrease in posterior facial height of -1.4 mm.

*Group 4: BSSA & LFI wire (N = 10; Table 7.8)*

No significant mean change in posterior facial height occurred at surgery. A significant decrease ($P < 0.001$) of -2.2 ± 0.55 mm occurred in the first six weeks. A smaller decrease of -0.7 mm was observed at T4. This change in posterior facial height of -2.9 mm was very significant ($P < 0.005$). Although the female group did not change at surgery, a significant ($P < 0.05$) reduction occurred at T3 (-2.2 mm). The males had a similar mean change at T3 but this was not significant.

Seven patients in the long term category gained a mean 0.4 ± 0.66 mm at surgery with a range of -3.2 to 1.2 mm. A significant decrease ($P < 0.05$) of -2.9 mm was measured between T2 and T3. Minimal changes were recorded at T4 and T5. The net change from T1 to T5 of -1.2 mm did not reach statistical significance.

Table 7.8: Changes in posterior facial height for bilateral sagittal split advancement (BSSA) with wire fixation.

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| Patients | M: 4 | F: 8 | Total: 12 | M: 3 | F: 7 | Total: 10 |
| T1-T2 (± se mm) | -0.9 | 1.6 | 0.8 ± 0.58 | 0.0 | 0.1 | 0.1 ± 0.53 |
| *t*-value | 2.40 | 2.40* | 1.32 | 2.49 | 0.22 | 0.15 |
| Min. | -1.9 | -0.5 | -1.9 | -1.7 | -1.6 | -1.7 |
| Max. | -0.1 | 4.7 | 4.7 | 3.3 | 1.3 | 3.3 |
| T2-T3 (± se mm) | -0.2 | -2.2 | -1.0 ± 0.60 | -2.1 | -2.2 | -2.2 ± 0.55 |
| *t*-value | 0.19 | 3.01* | 1.72 | 1.54 | 4.21* | 3.93** |
| Min. (mm) | -2.8 | -4.8 | -3.5 | -4.8 | -3.9 | -4.8 |
| Max. (mm) | 1.9 | 0.1 | 1.6 | -0.2 | -1.1 | -0.2 |
| T3-T4 (± se mm) | 0.4 | -1.2 | 0.4 ± 0.68 | -0.8 | -0.6 | -0.7 ± 0.54 |
| *t*-value | 0.42 | 1.60 | 0.54 | 0.36 | 0.81 | 1.21 |
| Min. | -1.9 | -4.1 | -2.9 | -2.6 | -3.5 | -3.5 |
| Max. | 2.4 | 1.1 | 2.8 | 0.3 | 0.5 | 0.5 |
| T1-T4 (± se mm) | -0.8 | -1.3 | -1.1 ± 0.43 | -2.9 | -2.0 | -2.3 ± 0.37 |
| Min. | -2.2 | -3.6 | -3.6 | -4.3 | -3.3 | -4.3 |
| Max. | 0.3 | 1.2 | 1.2 | -1.3 | -0.3 | -0.3 |
| Long term | M: 3 | F: 6 | Total: 9 | M: 1 | F: 6 | Total: 7 |
| T1-T2 (± se mm) | -1.0 | 1.5 | 0.7 ± 0.72 | 3.3 | -0.1 | 0.4 ± 0.66 |
| T2-T3 | 0.2 | -1.9 | -1.1 ± 0.79 | -4.8 | -2.4 | -2.9 ± 0.64* |
| T3-T4 | -0.3 | -1.3 | -1.0 ± 0.70 | 0.3 | 0.1 | 0.1 ± 0.18 |
| T4-T5 | 0.8 | -0.3 | -0.1 ± 0.39 | 2.9 | 0.1 | 0.5 ± 0.50 |
| T1-T5 | -0.3 | -1.5 | -1.1 ± 0.46 | 1.6 | -1.7 | -1.2 ± 0.52 |
| Min. | -2.2 | -3.0 | -3.0 | | -2.5 | -2.5 |
| Max. | 0.3 | 0.1 | 0.3 | | -0.6 | 1.6 |

* = $P < 0.05$
** = $P < 0.005$

7.2.2.3. *Anterior facial height (N-Me)*

*Group 1: BSSA screws (N = 10; Table 7.9)*

A mean increase of 5.2 ± 0.58 mm was measured following surgery. A proportion of this was lost at T3 (-1.0 ± 0.56 mm) and at T4 (0.5 ± 0.42 mm). None of the changes after the initial surgical change were significant. The net gain 12 months after surgery was 3.7 ± 0.52 mm.

The three males in the group had a mean increase of 4.3 ± 0.33 mm at surgery and lost small amounts at T3 (-0.2 ± 1.37 mm) and at T4 (1.0 ± 0.64 mm). This gave a net increase of 3.1 ± 0.60 mm after twelve months. The seven females gained 5.6 ± 0.79 mm at surgery. This decreased -1.4 ± 0.57 mm at T3 and minimally at T4 (0.3 ± 0.54 mm). The net gain due to surgery was 3.9 ± 0.70 mm at 12 months. The difference between sexes (0.7 mm) was not significant.

For the 2 long term cases, the male gained 4.9 mm at operation but lost -2.5 mm within six weeks. No loss occurred at T4 or T5. The net gain from surgery was 2.7 mm. The female increased 8.5 mm at T2 and lost -1.5 mm after six weeks. Small losses were noted at T4 (-0.5 mm) and T5 (-0.3 mm) giving a net increase of 6.2 mm two years after surgery.

**Table 7.9: Changes in anterior facial height for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 3** | **F: 7** | **Total: 10** | **M: 1** | **F: 7** | **Total: 8** |
| **T1-T2** (± se mm) | 4.3 | 5.6 | 5.2 ± 0.58 | 0.0 | 3.6 | 3.1 ± 0.78 |
| *t*-value | 1.29 | 2.60 | 8.93** | | 1.65 | 3.10** |
| Min. (mm) | 3.7 | 2.7 | 2.7 | | 1.1 | 0.0 |
| Max. (mm) | 4.9 | 8.5 | 8.5 | | 5.9 | 5.9 |
| **T2-T3** (± se mm) | -0.2 | -1.4 | -1.0 ± 0.57 | 1.1 | -1.5 | -1.2 ± 0.46 |
| *t*-value | 0.38 | 4.72** | 1.86 | | 1.78 | 2.53* |
| Min. | -2.5 | -4.5 | -4.5 | | -2.7 | -2.7 |
| Max. | 2.2 | 0 | 2.2 | | -0.8 | 1.1 |
| **T3-T4** (± se mm) | -1.0 | -0.3 | -0.5 ± 0.42 | 0.2 | -0.8 | -0.6 ± 0.50 |
| *t*-value | 0.41 | 0.13 | 1.16 | | 0.37 | 1.26 |
| Min. | -2.2 | -2.9 | -2.9 | | -3.2 | -3.2 |
| Max. | 0.0 | 1.2 | 1.2 | | 0.8 | 1.0 |
| **T1-T4*** (± se mm) | 3.1 | 3.9 | 3.7 ± 0.52 | 1.3 | 1.4 | 1.4 ± 0.61 |
| Min. | 2.3 | 0.7 | -3.4 | | -1.0 | -1.9 |
| Max. | 4.3 | 6.5 | 1.4 | | 3.5 | 1.3 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se mm) | 4.9 | 8.5 | 6.7 ± 1.84 | -2.8 | 0.0 | 0.6 ± 0.66 |
| **T2-T3** | -2.5 | -1.5 | -2.0 ± 0.51 | 0.0 | -1.6 | -0.2 ± 1.35 |
| **T3-T4** | 0.0 | -0.5 | -0.3 ± 0.27 | 0.9 | 2.8 | 0.0 ± 0.13 |
| **T4-T5** | 0.4 | -0.3 | 0.1 ± 0.35 | 0.7 | -0.2 | 0.3 ± 0.46 |
| **T1-T5** | 2.7 | 6.2 | 4.5 ± 1.73 | 2.0 | -0.6 | 0.7 ± 1.28 |

* = $P < 0.05$
** = $P < 0.005$

*Group 2: BSSA & LFI screws (N = 8; Table 7.9)*

The mean increase in anterior facial height of 3.1 ± 0.78 mm decreased -1.2 ± 0.46 mm by T3 and -0.6 ± 0.50 mm at T4. None of these changes were significant. The net gain 12 months after surgery was 1.4 ± 0.61 mm. Seven females showed increased anterior facial height ranging from 1.1 - 5.9 mm for a mean increase of 3.6 ± 0.74 mm. By T3, -1.5 ± 0.30 mm was lost and a further -0.8 ± 0.57 mm at T4.

The one male in this group was followed long term. No change occurred at surgery but there was an increase of 1.1 mm at T3 and at T4 (0.4 mm). The change between T4-T5 was 0.7 mm giving a net gain of 2.0 mm twenty-four months after surgery. The long term female had a surgical increase of 1.3 mm but decreased -1.6 mm at T3. Minor losses occurred at T4 (-0.1 mm) and T5 (-0.2 mm) giving a non-significant loss of 0.6 mm.

*Group 3: BSSA wire (N = 12; Table 7.10)*

A mean gain of 7.0 ± 0.53 mm was recorded for this group at surgery. A small loss in anterior facial height occurred after six weeks (-0.7 mm) with further loss at 12 months (-1.9 mm). This gave an average net gain of 4.3 ± 0.64 mm ranging from 1.1 - 8.2 mm. There were four males in this group who increased a mean 7.3 ± 0.78 mm (R: 5.1 - 8.7 mm). Loss at T3 was -1.0 ± 0.96 mm (R: -3.3 - 1.2 mm). A further loss of -1.7 ± 0.66 mm occurred by T4. This mean loss of -2.7 mm from T2-T4 gave a net gain of 4.6 ± 0.81 mm twelve months after surgery.

Females (N = 8) gained between 5.0 mm to 11.5 mm at surgery for a mean increase of 6.8 ± 0.72 mm. A small loss of -0.6 ± 0.21 mm occurred at T3 followed by a more substantial loss of -2.1 ± 0.77 mm (R: -5.1 - 1.4 mm). The mean loss between surgery and 12 months was -2.7 ± 0.59 mm giving a net gain of 4.1 ± 0 91 mm (R: 1.1 - 8.2 mm).

Six long term female patients had an average surgical increase of 7.0 ± 0.97 mm. Losses at T3 of -0.5 ± 0.27 mm, -1.9 ± 1.04 mm at T4 and a small gain of 0.5 ± 0.41 mm were observed. This gave a net gain of 5.0 ± 1.01 mm. The three long term males had a mean increase of 8.0 ± 0.38 mm which decreased -1.3 mm at T3. A marked loss of -2.3 ± 0.44 mm was measured at

T4 but this was partially regained at T5 (0.5 ± 0.71 mm). The overall gain resulting from surgery at 24 months was 5.0 ± 1.24 mm (R: 2.6 - 6.7 mm).

*Group 4: BSSA & LFI wire (N = 10; Table 7.10)*

The average gain in anterior facial height was 3.6 ± 1.06 mm with a range of -1.7 to 7.8 mm. At T3, there was a marked reduction of -2.3 ± 0.72 mm which continued at T4 (-1.5 ± 0.73 mm). The loss from T2-T4 was -3.3 ± 0.76 mm giving a net gain of only 0.3 ± 0.72 mm (R: -3.0 - 4.1 mm). The males (N = 3) averaged an increase of 5.2 ± 0.8 mm at T2 and had lost -3.3 ± 0.96 mm by six weeks. A loss of -1.9 ± 2.02 mm was seen at 12 months so that on average, no gain had resulted from surgery.

**Table 7.10: Changes in anterior facial height for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 4** | **F: 8** | **Total: 12** | **M: 3** | **F: 7** | **Total: 10** |
| **T1-T2** (± se mm) | 7.3 | 6.8 | 7.0 ± 0.53 | 5.2 | 3.0 | 3.6± 1.06 |
| *t*-value | 2.40 | 2.40* | 13.15** | 2.49 | 0.22 | 3.27** |
| Min. (mm) | 5.1 | 5.0 | 5.0 | 3.8 | -1.7 | -1.7 |
| Max. (mm) | 8.7 | 11.5 | 11.5 | 6.5 | 7.8 | 7.8 |
| **T2-T3** (± se mm) | -1.0 | -0.6 | -0.7 ± 0.35 | -3.3 | -1.7 | -2.3 ± 0.72 |
| *t*-value | 0.19 | 3.01* | 2.15 | 1.54 | 4.21* | 3.23* |
| Min. | -3.3 | -1.5 | -3.3 | -4.3 | -5.1 | -5.1 |
| Max. | 1.2 | 0.0 | 1.2 | -1.4 | 0.7 | 0.7 |
| **T3-T4** (± se mm) | -1.7 | -2.1 | -1.9± 0.52 | -1.9 | -1.2 | -1.5 ± 0.73 |
| *t*-value | 0.42 | 1.60 | 1.03 | 0.36 | 0.81 | 1.21 |
| Min. | -3.2 | -5.1 | -5.1 | -6.0 | -2.1 | -6.0 |
| Max. | 0 | 1.4 | 1.4 | 0.3 | 0.3 | 0.3 |
| **T1-T4*** (± se mm) | 4.6 | 4.1 | 4.3 ± 0.64 | -0.1 | 0.5 | 0.3 ± 0.72 |
| Min. | 2.9 | 1.1 | 1.1 | -0.8 | -3.0 | -3.0 |
| Max. | 6.7 | 8.2 | 8.2 | 1.3 | 4.1 | 4.1 |
| **Long term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se mm) | 8.0 | 7.0 | 7.3 ± 0.66** | 3.8 | 3.8 | 3.8 ± 1.22* |
| **T2-T3** | -1.3 | -0.5 | -0.8 ± 0.48 | -4.3 | -2.3 | -2.7 ± 0.85* |
| **T3-T4** | -2.3 | -1.9 | -2.1± 0.64* | -0.2 | -0.9 | -0.8 ± 0.41 |
| **T4-T5** | 0.5 | 0.5 | 0.5 ± 0.34 | 0.4 | -0.1 | 0.0 ± 0.20 |
| **T1-T5*** | 5.0 | 5.0 | 5.0 ± 0.74 | -0.3 | 1.0 | 0.8 ± 0.81 |
| Min. | 2.6 | 2.4 | 2.4 | | -1.5 | -1.8 |
| Max. | 6.7 | 8.2 | 8.2 | | 4.1 | 3.6 |

* = $P < 0.05$
** = $P < 0.005$

Seven females showed altered anterior facial height ranging from -1.7 to 7.8 mm with a mean of 3.0 ± 1.44 mm. At subsequent intervals, a mean of -1.7 mm was lost at T3 and -1.2 mm at T4 giving a mean loss of -2.5 mm between T2-T4. This gave a minimal net gain of 0.5 ± 1.02 mm (R: -3.0 - 4.1 mm).

Six long term female patients increased a mean of 3.8 ± 1.44 mm at surgery. This was rapidly lost at T3 (-2.3 mm) and T4 (-0.9 mm) so that the net gain after two years was 1.0 ± 0.99 mm (R: -1.5 - 4.1 mm). The one male patient increased 3.8 mm initially but lost -4.3 mm at T3. A small loss was measured at T4 (-0.2 mm) but there was a small gain at T5 (0.4 mm). The net loss after 24 months was -0.3 mm.

#### 7.2.2.4. *Mandibular plane angle (SNGoMe)*

*Group 1: BSSA screws (N = 10; Table 7.11)*

The mean mandibular plane angle at T1 was 34.2 ± 2.12° with a range of 22.8 to 46.6°. This angle increased in all intervals from T2 (1.9 ± 0.63°) to T4 (0.4 ± 0.37°) giving a net increase of 2.7 ± 0.54° over the initial value. The preoperative mandibular plane angle was 33.9° in males and 34.3° in females. The females increased at all intervals resulting in a mean increase of 3.1° at 12 months. The males followed a similar pattern but the magnitude was smaller. The net change at T4 was 1.6°.

The two long term cases both had initial increases in mandibular plane angle following surgery. The male subject had a preoperative mandibular plane angle of 27.1° which increased 2.5° at T2, decreased -0.3° at T3 and -1.0° at T4. There was no change at T5. This gave a net increase of 1.2°. The female patient had a mandibular plane angle of 36.1° which increased 4.6° at surgery and 1.9° at T3. Small changes at T4 (0.2°) and T5 (1.6°) gave a net increase of 6.4° at two years.

*Group 2: BSSA & LFI screws (N = 8; Table 7.11)*

The preoperative mandibular plane angle ranged from 30.9° to 51.7° with a mean of 39.9°. A mean decrease of -1.3 ± 0.90° occurred at surgery. The angle increased 0.5° at T3 but decreased at T4 (-0.5°) giving a net change of -0.7 ± 0.89° after 12 months. The male patient started with an angle of 36.6° which changed little over the period of observation. The 7 females had an average mandibular plane angle of 40.0° preoperatively. The mean changes in the mandibular plane angle were small.

**Table 7.11: Changes in mandibular plane angle for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 3** | **F: 7** | **Total: 10** | **M: 1** | **F: 7** | **Total: 8** |
| **T1-T2** (± se deg) | 1.7 | 1.9 | 1.9 ± 0.63 | -0.9 | -1.3 | -1.3 ± 0.90 |
| *t*-value | 4.90* | 2.15 | 3.01* | | 1.26 | 1.39 |
| Min. (deg) | 1.4 | -1.5 | -1.5 | | -5.3 | -5.3 |
| Max. (deg) | 2.5 | 4.6 | 4.6 | | 3.81 | 3.8 |
| **T2-T3** (± se deg) | 0.2 | 0.5 | 0.4 ± 0.36 | 1.1 | 0.3 | 0.5 ± 0.30 |
| *t*-value | 0.29 | 1.11 | 1.13 | | 1.01 | 1.48 |
| Min. | -0.7 | -1.4 | -1.4 | | -0.7 | -0.7 |
| Max. | 1.7 | 1.9 | 1.9 | | 1.4 | 1.4 |
| **T3-T4** (± se deg) | -0.4 | 0.7 | 0.4 ± 0.37 | -0.6 | -0.5 | -0.5 ± 0.40 |
| *t*-value | 0.80 | 1.55 | 0.97 | | 1.09 | 1.32 |
| Min. | -0.9 | -0.8 | -0.9 | | -1.8 | -1.8 |
| Max. | 0.6 | 2.5 | 2.5 | | 1.3 | 1.3 |
| **T1-T4**** (± se deg) | 1.6 | 3.1 | 2.7 ± 0.54 | -0.4 | -0.8 | -0.7 ± 0.89 |
| Min. | 1.2 | 0.7 | 0.7 | | -5.0 | -5.0 |
| Max. | 2.2 | 6.8 | 6.8 | | 2.6 | 2.6 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se deg) | 2.5 | 4.6 | 3.6 ± 1.10 | -0.9 | -0.5 | -0.7 ± 0.19 |
| **T2-T3** | -0.3 | 1.9 | 0.8 ± 1.12 | 1.1 | -0.6 | 0.3± 0.86 |
| **T3-T4** | -1.0 | 0.2 | -0.3 ± 0.58 | -0.6 | -1.1 | -0.8 ± 0.22 |
| **T4-T5** | 0.0 | 1.6 | 0.8 ± 0.80 | -0.4 | 0.5 | 0.1 ± 0.43 |
| **T1-T5** | 1.2 | 8.4 | 4.8 ± 3.59 | -0.7 | -1.7 | -1.2 ± 0.46 |

* = $P < 0.05$
** = $P < 0.005$

The long term female patient had a preoperative mandibular plane angle of 35.0° which decreased -0.5° at surgery and at 6 weeks (-0.6°). A further loss at T4 of -1.1° was partially compensated by a gain of 0.5° at T5. The net effect was a loss of -1.7° two years after surgery. In the male, a decrease of

-0.9° was measured at T2 after a preoperative value of 36.6°. There was minimal change over the long term.

*Group 3: BSSA wire (N = 12; Table 7.12)*

The preoperative mandibular plane angle averaged 31.1 ± 1.37° and increased 3.1° with surgery. A further increase of 1.7° occurred at T3 followed by a decrease of -0.9°. The net effect at 12 months was an increase of 3.3 ± 0.47°.

**Table 7.12: Changes in mandibular plane angle for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | M: 4 | F: 8 | Total: 12 | M: 3 | F: 7 | Total: 10 |
| **T1-T2** (± se deg) | 4.2 | 2.4 | 3.0 ± 0.46 | 2.6 | -0.2 | 0.7 ± 1.18 |
| *t*-value | 11.94** | 4.41** | 6.69** | 1.96 | 0.20 | 0.89 |
| Min. (deg) | 3.4 | 0.4 | 0.4 | 0.0 | -6.5 | -6.5 |
| Max. (deg) | 5.2 | 4.9 | 5.2 | 4.3 | 4.7 | 4.7 |
| **T2-T3** (± se deg) | 0.4 | 1.9 | 1.3 ± 0.52 | 0.2 | 0.5 | 0.4 ± 0.42 |
| *t*-value | 0.34 | 4.74** | 2.55* | 0.52 | 0.83 | 1.02 |
| Min. | -2.5 | 0.5 | -2.5 | -0.7 | -1.6 | -1.6 |
| Max. | 3.1 | 3.1 | 3.1 | 0.8 | 1.9 | 1.9 |
| **T3-T4** (± se deg) | -1.1 | -0.7 | -0.9 ± 0.41 | -1.9 | 0.8 | -0.1 ± 0.61 |
| *t*-value | 2.31 | 1.20 | 2.12 | 2.12 | 1.34 | 0.32 |
| Min. | -1.9 | -3.0 | -3.0 | -2.9 | -0.4 | -2.9 |
| Max. | 0.3 | 1.8 | 1.8 | -0.1 | 2.9 | 2.9 |
| **T1-T4**** (± se deg) | 3.5 | 3.2 | 3.3 ± 0.47 | 0.9 | 1.2 | 1.1 ± 0.59 |
| Min. | 2.1 | 0.6 | 0.6 | 0.5 | -1.7 | -1.7 |
| Max. | 5.4 | 6.5 | 6.5 | 1.4 | 4.2 | 4.2 |
| **Long term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se deg) | 4.5 | 2.9 | 3.4 ± 0.48 | 0.0 | 1.1 | 0.9 ± 1.00 |
| **T2-T3** | 0.0 | 2.0 | 1.3 ± 0.71 | 0.6 | 0.2 | 0.3 ± 0.56 |
| **T3-T4** | -1.0 | -0.6 | -0.7 ± 0.52 | -0.1 | 0.4 | 0.3 ± 0.25 |
| **T4-T5** | -0.8 | 0.6 | 0.1 ± 0.41 | -1.8 | 0.0 | -0.2 ± 0.35 |
| **T1-T5†** | 2.7 | 4.3 | 3.8 ± 0.61 | -1.3 | 1.7 | 1.3 ± 0.97* |
| Min. | 1.4 | 1.3 | 1.3 | | -1.1 | -1.3 |
| Max. | 4.4 | 6.7 | 6.7 | | 5.4 | 5.4 |

* = $P < 0.05$
** = $P < 0.005$
† = Student's unpaired *t*-test ($P < 0.05$): statistical difference between group 3 and group 4.

The eight females in the group averaged an increase of 2.4° at T2, 1.9° at T3 and a small loss at T4 (0.71°) resulting in a net increase of 3.1 ± 0.64° (R: 0.6 - 6.5°). Similar increases of 3.5 ± 0.70° were recorded for the four males. The nine long term patients underwent minor changes at T5 (0.1°) providing a long term increase of 3.8 ± 0.62°. There was no statistical difference between sexes for the long term mandibular plane values.

*Group 4: BSSA & LFI wire (N = 10; Table 7.12)*

Ten patients contributed to the mandibular plane average of 37.1 ± 1.75° (R: 27.0 - 46.6°). Small changes occurred at T2 (0.7°), T3 (0.4°) and T4 (-0.1°) for this group of patients. The net gain was 1.1 ± 0.59° at T4 compared to preoperative values.

Both sexes showed minor changes for all intervals. The only period where there was a statistical difference ($P < 0.05$) was during T3-T4; females increased 0.8° compared to -1.9° for males. Conservative changes occurred for the long term patients at all intervals providing a net change ranging from -1.1 to 5.4° .

## *7.3. SEGMENTAL INTER-RELATIONSHIPS*

### *7.3.1. Gonial angle (ArGoMe)*

*Group 1: BSSA screws (N = 10; Table 7.13)*

The gonial angle increased a mean 5.1 ± 0.86° at T2 with a range of 0.7° to 9.5°. This angle changed minimally thereafter giving a net increase of 5.4 ± 0.66° over the initial value.

The two long term cases both had initial increases in gonial angle following surgery. The male subject increased 7.8° at T2, decreased -1.0° at T3, -1.1° at T4 and T5(-0.9°). This gave a net increase of 4.9° after 24 months. The female patient increased 9.5° at surgery and decreased -2.6° at T3. Small changes at T4 (-0.2°) and T5 (-0.4°) gave a net increase of 6.4° at two years.

*Group 2: BSSA & LFI screws (N = 8; Table 7.13)*

The gonial angle showed a small mean increase of 2.6 ± 1.15° (R:-2.1 - 6.3°). Small mean changes of 0.3 ± 0.51° at T3 and T4 (0.2°) gave a net change of 3.1 ± 1.02° after 12 months. None of the changes after the initial surgical change were statistically significant.

The long term female patient increased 5.0° at surgery and at 6 weeks decreased -1.3°. A small gain at T4 of 1.0° and a loss at T5 of -0.7° left a net gain of 4.0° two years after surgery. In the male, an increase of 3.8° was measured at T2. Small positive gains occurred at T3 (1.0°) and T4 (0.6°). A minor negative change at T5 (-0.1°) resulted in a net gain of 5.1°.

**Table 7.13: Changes in gonial angle for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | M:3 | F:7 | Total:10 | M:1 | F:7 | Total:8 |
| **T1-T2** (± se deg) | 5.3 | 5.0 | 5.1 ± 0.86 | 3.8 | 2.4 | 2.6 ± 1.15 |
| *t*-value | 3.63 | 4.46 | 5.96** | | 1.84 | 2.25 |
| Min. (deg) | 2.7 | 0.7 | 0.7 | | -2.1 | -2.1 |
| Max. (deg) | 7.8 | 9.5 | 9.5 | | 6.3 | 6.3 |
| **T2-T3** (± se deg) | 0.3 | 0.4 | 0.3 ± 0.51 | 0.8 | 0.2 | 0.3 ± 0.51 |
| *t*-value | 0.41 | 0.50 | 0.64 | | 1.98 | 0.59 |
| Min. | -1.0 | -2.6 | -2.6 | | -1.3 | -1.3 |
| Max. | 1.1 | 2.4 | 2.4 | | 1.8 | 1.8 |
| **T3-T4** (± se deg) | -1.8 | 0.7 | 0.0 ± 0.54 | 0.6 | 0.1 | 0.2 ± 0.49 |
| *t*-value | 3.08 | 1.44 | 0.03 | | 0.19 | 0.37 |
| Min. | -2.9 | -0.6 | -2.9 | | -2.1 | -2.1 |
| Max. | -1.1 | 3.4 | 3.4 | | 1.2 | 1.2 |
| **T1-T4**** (± se deg) | 3.8 | 6.1 | 5.4 ± 0.66 | 5.2 | 2.8 | 3.1 ± 1.02 |
| Min. | 0.6 | 4.5 | 0.6 | | -0.7 | -0.7 |
| Max. | 5.7 | 8.7 | 8.7 | | 6.8 | 6.8 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se deg) | 7.8 | 9.5 | 8.7 ± 0.86 | 3.8 | 5.0 | 4.4 ± 0.59 |
| **T2-T3** | -1.0 | -2.6 | -1.8 ± 0.77 | 0.8 | -1.3 | -0.2 ± 1.04 |
| **T3-T4** | -1.1 | -0.2 | -0.6 ± 0.44 | 0.6 | 1.0 | 0.8 ± 0.19 |
| **T4-T5** | -0.9 | -0.4 | -0.8 ± 0.52 | -0.1 | -0.7 | -0.4 ± 0.30 |
| **T1-T5** | 4.9 | 6.4 | 5.7 ± 1.35 | 5.1 | 4.0 | 4.5 ± 0.56 |

* = $P < 0.05$
** = $P < 0.005$

<u>*Group 3: BSSA wire (N = 12; Table 7.14)*</u>

The gonial angle averaged an increase of 7.3 ± 1.22° with surgery. A further increase of 1.3° occurred at T3 followed by a decrease of -0.5°. The net effect at 12 months was a gain of 7.9 ± 1.34°. The eight females in the group averaged gains of 6.4° at T2, 0.9° at T3 and a small loss at T4 (-0.6°) resulting in a net gain of 6.5 ± 1.52° (R: 0.3 - 14.9°). An average net increase of 10.8 ± 2.22° (5.9 - 16.6°) was recorded for the four males. The difference between sexes was not significant ($t$ = 1.62). The nine long term patients underwent minor changes at T5 (-0.8°) providing a long term increase of 8.2 ± 1.35°.

*Group 4: BSSA & LFI wire (N = 10; Table 7.14)*

Gonial angle increased 6.9 ± 0.62° (R: 5.1 - 11.2°) at surgery and at T3 (2.2 ± 0.46°). A small loss at T4 of 0.6 ± 0.66° resulted in a net gain of 8.3 ± 0.85° (R: 3.8 - 11.5°). The seven females in this group initially increased 6.0 ± 0.43° at operation and 2.2° at T3. The small loss at T4 (0.2°) gave a residual increase of 7.6 ± 1.09° (R: 3.8 - 11.1°). In the long term, the seven patients lost a mean -0.3° (R: -2.5 - 3.7°) so that the net change (T1-T5) after 2 years was 7.3 ± 0.92° (R: 2.5 - 10.4°).

**Table 7.14: Changes in gonial angle for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 4** | **F: 8** | **Total: 12** | **M: 3** | **F: 7** | **Total: 10** |
| **T1-T2** (± se deg) | 9.0 | 6.4 | 7.3 ± 1.22 | 9.1 | 6.0 | 6.9 ± 0.62 |
| *t*-value | 5.68** | 6.95** | 5.94** | 2.49 | 4.49** | 11.23** |
| Min. (deg) | 6.9 | -1.8 | -1.8 | 7.5 | 5.1 | 5.1 |
| Max. (deg) | 12.8 | 13.4 | 13.4 | 11.2 | 8.2 | 11.2 |
| **T2-T3** (± se deg) | 2.1 | 0.9 | 1.3 ± 0.88 | 2.1 | 2.2 | 2.2 ± 0.46 |
| *t*-value | 3.5* | 5.81** | 1.49 | 0.03 | 0.28 | 4.72** |
| Min. | 0.6 | -6.6 | -6.6 | 0.1 | 1.2 | 0.1 |
| Max. | 2.9 | 4.0 | 4.0 | 3.4 | 3.7 | 3.7 |
| **T3-T4** (± se deg) | -0.3 | -0.6 | -0.5 ± 0.65 | -1.3 | -0.2 | -0.6 ± 0.66 |
| *t*-value | 0.24 | 2.06* | 0.76 | 0.36 | 1.66 | 0.89 |
| Min. | -3.0 | -2.5 | -3.0 | -3.0 | -1.9 | -3.0 |
| Max. | 1.4 | 4.5 | 4.5 | 1.2 | 2.8 | 2.8 |
| **T1-T4**** (± se deg) | 10.8 | -6.5 | 7.9 ± 1.34 | 10.0 | 7.6 | 8.3 ± 0.85 |
| Min. | 5.9 | 0.3 | 0.3 | 8.8 | 3.8 | 3.8 |
| Max. | 16.6 | 14.9 | 16.6 | 11.5 | 11.1 | 11.5 |
| **Long term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se deg) | 9.1 | 7.0 | 7.7 ± 1.16 | 7.5 | 5.7 | 5.9 ± 0.35 |
| **T2-T3** | 1.8 | 2.1 | 2.0 ± 0.51 | 0.1 | 2.4 | 2.0 ± 0.66 |
| **T3-T4** | -0.2 | -0.4 | -0.4 ± 0.88 | 1.2 | -0.2 | 0.1 ± 0.86 |
| **T4-T5** | -0.6 | -0.9 | -0.8 ± 0.52 | -1.3 | -0.1 | -0.3 ± 0.40 |
| **T1-T5*** | 10.1 | 7.3 | 8.2 ± 1.35 | 7.5 | 7.3 | 7.3 ± 0.92 |
| Min. | 6.0 | 3.1 | 3.1 | | 2.5 | 2.5 |
| Max. | 15.5 | 13.9 | 15.5 | | 10.4 | 10.4 |

* = $P < 0.05$
** = $P < 0.005$

### 7.3.2. *Ramal angle (SNArGo)*

*Group 1: BSSA screws (N = 10; Table 7.15)*

The mean change in ramal angle at T2 was -2.9 ± 0.73° with a range of -5.4 to 1.0°. This angle increased in the intervals from T3 (0.1 ± 0.64°) to T4 (0.5 ± 0.74°) giving a net decrease of -2.5 ± 0.66° over the initial value. No statistical difference was demonstrated between the sexes for this variable.

The two long term cases both had initial decreases in ramal angle following surgery. The male subject decreased -5.4° at T2 but changed minimally thereafter. This gave a net loss of -3.7°. The female patient decreased -4.9° at surgery but gained 4.5° at T3. Minor changes at T4 (0.4°) and T5 (2.0°) gave a net increase of 2.0° at two years.

**Table 7.15: Changes in ramal angle for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 3** | **F: 7** | **Total: 10** | **M: 1** | **F: 7** | **Total: 8** |
| **T1-T2** (± se deg) | -3.6 | -2.7 | -2.9 ± 0.73 | -4.7 | -3.7 | -3.8 ± 1.10 |
| *t*-value | 3.07 | 2.79* | 4.02** | | 2.94* | 3.49* |
| Min. (deg) | -5.4 | -4.9 | -5.4 | | -8.5 | -8.5 |
| Max. (deg) | -1.4 | 1.0 | 1.0 | | 0.9 | 0.9 |
| **T2-T3** (± se deg) | -0.1 | 0.1 | 0.1 ± 0.64 | 0.3 | 0.1 | 0.2 ± 0.32 |
| *t*-value | 0.06 | 0.17 | 0.14 | | 0.32 | 0.46 |
| Min. | -1.8 | -2.1 | -2.1 | | -1.2 | -1.2 |
| Max. | 1.0 | 4.5 | 4.5 | | 1.5 | 1.5 |
| **T3-T4** (± se deg) | 1.4 | -0.1 | 0.4 ± 0.36 | -1.2 | -0.6 | -0.7 ± 0.74 |
| *t*-value | 2.21 | 0.15 | 1.06 | | 0.72 | 0.96 |
| Min. | 0.1 | -1.6 | -1.6 | | -3.0 | -3.0 |
| Max. | 2.0 | 1.0 | 2.0 | | 2.5 | 2.5 |
| **T1-T4**** (± se deg) | -2.3 | -2.5 | 2.5 ± 0.66 | -5.6 | -3.5 | -3.8 ± 0.70 |
| Min. | -4.5 | -4.9 | -4.9 | | -6.9 | -6.9 |
| Max. | 1.6 | 0.0 | 1.6 | | -0.3 | -0.3 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se deg) | -5.4 | -4.9 | -5.1 ± 0.24* | -4.7 | -5.5 | -5.1 ± 0.40* |
| **T2-T3** | 0.7 | 4.5 | 2.6 ± 1.89 | 0.3 | 0.7 | 0.5 ± 0.19 |
| **T3-T4** | 0.1 | 0.4 | 0.3 ± 0.13 | -1.2 | -2.0 | -1.6 ± 0.42 |
| **T4-T5** | 0.9 | 2.0 | -1.5 ± 0.57 | -0.2 | 1.2 | 0.5 ± 0.74 |
| **T1-T5** | -3.7 | 2.0 | -0.8 ± 2.82 | -5.9 | -5.6 | -5.7 ± 0.11 |

* = $P < 0.05$
** = $P < 0.005$

*Group 2: BSSA & LFI screws (N = 8; Table 7.15)*

The change in ramal angle at T2 ranged from -8.5° to 0.9° with a mean of -3.8°. There was a non-significant mean change of 0.1 ± 0.32° at T3 and a decrease at T4 (-0.7°) giving a net change of -3.8 ± 0.70° after 12 months.

The female patient decreased -5.5° at surgery and experienced a small increase at 6 weeks (0.7°). There was further fluctuation at T4 (-2.0°) and at T5 (1.2°). The net effect was a decrease of -5.6° two years after surgery. In the male, a decrease of -4.7° was measured at T2. Changes at T4 (-1.2°) and T5
(-0.2°) resulted in a net loss of -5.9°.

*Group 3: BSSA wire (N = 12; Table 7.16)*

The surgical change in ramal angle resulted in a decrease of -4.2°. There was no change at T3 and minimal change at T4 (-0.4°). The net effect at 12 months was a decrease of -4.7 ± 1.09°.

The eight females in the group averaged change of -4.0° at T2, a small increase at T3 (1.0°) and a small loss at T4 resulting in a net decrease of -3.4°. The four males had a different postoperative course after a similar decrease of -4.8°. Changes at T3 (-1.7°) and T4 (-0.8°) gave a net value of -7.3° at twelve months. The nine long term patients underwent a similar pattern of change to the intermediate term patients. Minor changes at T5 (1.0 ± 0.46°) provided a long term decrease of -4.5 ± 1.34°. There was no statistical difference between sexes for the long term ramal angle values.

*Group 4: BSSA & LFI wire (N = 10; Table 7.16)*

The ten patients in this group decreased an average of -6.1 ± 1.16° at T2. A significant ($P < 0.05$) decrease occurred at T3 (-1.7°). The net change at twelve months was -7.3 ± 1.22°. Both sexes showed minor changes for all intervals and none of the differences were statistically significant.

Seven patients (6 females and 1 male) who satisfied T5 criteria had results which were similar to the rest of the sample. The net gain at T4 was -6.5 ± 0.66° after 12 months. A small loss of -0.2° at T5 gave a resultant gain of -6.1 ± 1.47° at 24 months.

**Table 7.16: Changes in ramal angle for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 4** | **F: 8** | **Total: 12** | **M: 3** | **F: 7** | **Total: 10** |
| **T1-T2** (± se deg) | -4.8 | -4.0 | -4.2 ± 1.22 | -6.5 | -5.9 | -6.1 ± 1.16 |
| *t*-value | 3.34* | 2.27 | 3.47* | 5.81* | 3.58* | 5.23** |
| Min. (deg) | -8.5 | -10.9 | -10.9 | -7.8 | -14.6 | -14.6 |
| Max. (deg) | -2.3 | 3.5 | 3.5 | -4.3 | -1.5 | -1.5 |
| **T2-T3** (± se deg) | -1.7 | 1.0 | 0.0 ± 0.98 | -1.9 | -1.6 | -1.7 ± 0.67 |
| *t*-value | 2.28 | 0.72 | 0.02 | 1.53 | 1.84 | 2.56* |
| Min. | -3.1 | -1.6 | -3.1 | -3.6 | -4.8 | -4.8 |
| Max. | 0.2 | 9.0 | 9.0 | 0.5 | 0.6 | 0.6 |
| **T3-T4** (± se deg) | -0.8 | -0.1 | -0.4 ± 0.67 | -0.7 | 1.0 | 0.4 ± 0.60 |
| *t*-value | 0.88 | 0.12 | 0.54 | 1.38 | 1.15 | 0.59 |
| Min. | -2.8 | -4.6 | -4.6 | -1.3 | -1.9 | -1.9 |
| Max. | 1.5 | 3.1 | 3.1 | 0.3 | 3.2 | 3.2 |
| **T1-T4**** (± se deg) | -7.3 | -3.4 | -4.7 ± 1.09 | -9.1 | -6.6 | -7.3 ± 1.22 |
| Min. | -11.2 | -10.3 | -11.2 | -10.1 | -10.9 | -10.9 |
| Max. | -3.8 | 2.0 | 2.0 | -8.3 | 0.3 | 0.3 |
| **Long term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se deg) | -4.5 | -4.1 | -4.2 ± 1.13* | -7.5 | -4.4 | -4.9 ± 0.88** |
| **T2-T3** | -1.8 | -0.1 | -0.7 ± 0.52 | 0.5 | -2.2 | -1.7 ± 0.88 |
| **T3-T4** | -0.8 | -0.1 | -0.4 ± 0.93 | -1.3 | 0.4 | 0.1 ± 0.72 |
| **T4-T5** | -0.2 | 1.5 | 1.0 ± 0.46 | -0.5 | 0.2 | 0.1 ± 0.66 |
| **T1-T5*** | -7.4 | -3.0 | -4.5 ± 1.34 | -8.8 | -5.7 | -6.1 ± 1.47 |
| Min. | 1.4 | 1.3 | 1.3 | | -10.2 | -10.2 |
| Max. | 4.4 | 6.7 | 6.7 | | 0.6 | 0.6 |

* = $P < 0.05$
** = $P < 0.005$

## *7.4. DENTOSKELETAL CHANGES*

### *7.4.1. Maxillary incisal angle (SN-ASIS)*

*Group 1: BSSA screws (N = 10; Table 7.17)*

The maxillary incisal angle changed minimally at T2 with a mean of -0.4 ± 0.75°. This angle did not change significantly at T3 (-0.9°) but decreased -3.7 ± 1.01° (*P* < 0.005) between T3-T4 reflecting postoperative orthodontic treatment. This change of -5.0° was highly significant in the female population. The net change was a reduction of -5.3 ± 1.09° compared to the initial value.

The two long term cases both had minimal reductions in maxillary incisal angle following surgery. The male subject decreased -1.8° between T2-T4. The net reduction after 24 months was -2.8°. The female patient did not change significantly at T2 or T3. Incisal retraction between T3-T4 of -6.5° resulted in a change of -7.4° and gave a net reduction of -10.2° at two years.

*Group 2: BSSA & LFI screws (N = 8; Table 7.17)*

The maxillary incisal angle showed a small mean reduction of -2.1 ± 1.27° (R:-6.6 - 2.4°). Mean changes of -3.7 ± 1.78° at T3 and T4 (2.9 ± 1.19°) gave a net change of -3.1 ± 1.27° after 12 months. None of the changes after the initial surgical change were statistically significant.

The long term female patient increased 2.1° at surgery and at 6 weeks (2.5°). A small loss at T4 of -1.9° left a net gain of 3.1° two years after surgery. In the male, an increase of 1.3° was measured at T2. A considerable change occurred at T3 (-8.9°). Increased proclination between T3-T4 (4.3°) left a minor change of -2.5° at 24 months.

**Table 7.17: Changes in maxillary incisal angle for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 3** | **F: 7** | **Total: 10** | **M: 1** | **F: 7** | **Total: 8** |
| **T1-T2** (± se deg) | -0.5 | -0.3 | -0.4 ± 0.75 | 1.3 | -2.6 | -2.1 ± 1.27 |
| *t*-value | 0.78 | 0.31 | 0.51 | | 1.91 | 1.65 |
| Min. (deg) | -1.7 | -3.9 | -3.9 | | -6.6 | -6.6 |
| Max. (deg) | 0.5 | 4.6 | 4.6 | | 2.4 | 2.4 |
| **T2-T3** (± se deg) | -1.1 | -0.8 | -0.9 ± 0.74 | -8.9 | -2.9 | -3.7 ± 1.78 |
| *t*-value | 0.81 | 0.84 | 1.21 | | 1.55 | 2.09 |
| Min. (deg) | -3.9 | -5.6 | -5.6 | | -10.0 | -10.0 |
| Max. (deg) | 0.5 | 2.1 | 2.1 | | 2.5 | 2.5 |
| **T3-T4** (± se deg) | -1.6 | -5.0 | -4.0 ± 0.95 | 4.3 | 2.7 | 2.9 ± 1.19 |
| *t*-value | 1.24 | 4.85** | 4.23** | | 1.92 | 2.43 |
| Min. | -3.3 | -8.9 | -8.9 | | -1.9 | -1.9 |
| Max. | 0.9 | -0.2 | 0.9 | | 8.4 | 8.4 |
| **T1-T4**** (± se deg) | -3.2 | -6.2 | -5.3 ± 1.09** | -3.3 | -3.0 | -3.1 ± 1.27* |
| Min. | -6.7 | -10.8 | -10.8 | | -6.5 | -6.5 |
| Max. | -0.8 | -1.3 | -0.8 | | 2.7 | 2.7 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se deg) | -0.3 | -1.1 | -0.7 ± 0.40 | 1.3 | 2.1 | 1.7 ± 0.40 |
| **T2-T3** | 0.5 | -0.9 | -0.2 ± 0.70 | -8.9 | 2.5 | -3.2 ± 5.7 |
| **T3-T4** | -2.3 | -6.5 | -4.4 ± 2.1 | 4.3 | -1.9 | 1.2 ± 3.1 |
| **T4-T5** | -0.7 | -1.7 | -1.2 ± 0.50 | 0.8 | 0.4 | 0.6 ± 0.20 |
| **T1-T5** | -2.8 | -10.2 | -6.5 ± 3.7 | -2.5 | 3.1 | 0.3 ± 2.80 |

* = $P < 0.05$
** = $P < 0.005$

## *Group 3: BSSA wire (N = 12; Table 7.18)*

The maxillary incisal angle remained static at surgery but decreased -2.0° ($P < 0.05$) at T3. The net effect at 12 months was a slight incisal retraction of -2.1 ± 1.04°. The mean value for the eight females in the group did not change at T2, but statistically significant incisal retraction (-2.1°) was observed at T3. The net change at T4 was a reduction in maxillary incisal angle of -2.5°. An average net change of -1.1° (R: -2.8 - 1.0°) was recorded for the four males. The difference between sexes was not significant. The nine long term patients underwent minor changes at T5 providing long term incisal retraction of -3.7 ± 1.71°.

*Group 4: BSSA & LFI wire (N = 10; Table 7.18)*

The mean maxillary incisal angle did not alter significantly at surgery and at T3 (-1.3 ± 1.36°) minimal retraction was measured. Proclination of the maxillary incisors observed in the 12 months (2.4 ± 2.58°) was not significant and there was minimal change compared to the preoperative mean value. The seven females in this group initially increased 2.0° at operation and decreased -1.4° at T3. There was no change in the mean value after 12 months compared to the presurgical value. In the long term, the seven patients lost a mean -2.0° so that the net change (T1-T5) after 2 years was -2.4°.

**Table 7.18: Changes in maxillary incisal angle for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 4** | **F: 8** | **Total: 12** | **M: 3** | **F: 7** | **Total: 10** |
| **T1-T2** (± se deg) | -0.7 | 0.3 | 0.0 ± 0.48 | -3.3 | 2.0 | 0.4 ± 2.12 |
| *t*-value | 1.25 | 0.51 | 0.02 | 1.00 | 0.78 | 0.19 |
| Min. (deg) | -1.9 | -2.8 | -2.8 | -9.7 | -3.3 | -9.7 |
| Max. (deg) | 0.7 | 3.2 | 3.2 | 1.6 | 13.8 | 13.8 |
| **T2-T3** (± se deg) | -1.7 | -2.1 | -2.0 ± 0.70 | -1.1 | -1.4 | -1.3 ± 1.36 |
| *t*-value | 1.17 | 2.57* | 2.80* | 0.34 | 0.96 | 0.94 |
| Min. | -5.8 | -5.3 | -5.8 | -6.8 | -6.3 | -6.8 |
| Max. | 0.6 | 0.6 | 0.6 | 4.3 | 2.2 | 4.3 |
| **T3-T4** (± se deg) | 1.3 | -1.5 | -0.5 ± 1.11 | 8.3 | -1.2 | 2.4 ± 2.58 |
| *t*-value | 1.71 | 0.92 | 0.43 | 2.06 | 0.51 | 0.92 |
| Min. | -0.5 | -6.7 | -6.7 | 0.5 | -7.4 | -7.4 |
| Max. | 2.8 | 5.2 | 5.2 | 13.9 | 6.7 | 13.9 |
| **T1-T4** (± se deg) | -1.1 | -2.5 | -2.1 ± 1.04 | 3.9 | -0.5 | 0.8 ± 1.72 |
| Min. | -2.8 | -10.5 | -10.5 | -2.2 | -8.9 | -8.9 |
| Max. | 1.0 | 4.0 | 4.0 | 8.5 | 6.9 | 8.5 |
| **Long term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se deg) | -0.3 | 0.2 | 0.0 ± 0.57 | -1.9 | 0.8 | 0.4 ± 2.28 |
| **T2-T3** | -2.3 | -1.3 | -1.7 ± 0.82 | -0.8 | -0.2 | -0.3 ± 0.79 |
| **T3-T4** | 0.8 | -3.5 | -1.9 ± 1.13 | 0.5 | -1.0 | -0.7 ± 2.33 |
| **T4-T5** | -1.6 | -0.3 | -0.7 ± 1.21 | 1.9 | -1.6 | -1.1 ± 1.53 |
| **T1-T5** | -3.4 | -3.8 | -3.7 ± 1.71 | -0.3 | -2.4 | -2.1 ± 1.04 |
| Min. | -5.3 | -13.0 | -13.0 | | -0.7 | -0.7 |
| Max. | -2.3 | 1.8 | 1.8 | | 1.4 | 1.4 |

* = $P < 0.05$

### 7.4.2. *Interincisal angle*

<u>*Group 1: BSSA screws (N = 10; Table 7.19)*</u>

The mean change in interincisal angle was -1.2 ± 1.60° with a range of -9.2° to 5.5°. There was no mean change at T3 and limited movement at T4. The T1-T4 value of 0.8 ± 1.61° represented a minimal net change after 12 months.

The three males had a mean decrease of -2.2° at surgery with little alteration in the intermediate period. The net increase of 1.6° after 12 months was not statistically significant.

**Table 7.19: Changes in interincisal angle for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 3** | **F: 7** | **Total: 10** | **M: 1** | **F: 7** | **Total: 8** |
| **T1-T2** (± se deg) | -2.2 | -0.1 | -1.2 ± 1.60 | 5.2 | 4.6 | 4.7 ± 1.93 |
| *t*-value | 1.23 | 0.32 | 0.73 | | 2.09 | 2.45* |
| Min. (deg) | -4.1 | -9.2 | -9.2 | | -1.7 | -1.7 |
| Max. (deg) | 1.4 | 5.5 | 5.5 | | 11.7 | 11.7 |
| **T2-T3** (± se deg) | 1.4 | -0.2 | 0.3 ± 1.64 | 13.5 | -1.0 | 1.1 ± 2.25 |
| *t*-value | 0.56 | 0.08 | 0.18 | | 0.95 | 0.48 |
| Min. | -1.7 | -8.8 | -8.8 | | -4.1 | -4.1 |
| Max. | 6.4 | 10.5 | 10.5 | | 2.4 | 13.5 |
| **T3-T4** (± se deg) | 2.4 | 1.4 | 1.7 ± 1.58 | -1.2 | -3.9 | -3.5 ± 2.30 |
| *t*-value | 2.47 | 0.61 | 1.07 | | 1.44 | 1.51 |
| Min. | 0.5 | -5.8 | -5.8 | | -13.7 | -13.7 |
| Max. | 3.7 | 8.3 | 8.3 | | 2.0 | 2.0 |
| **T1-T4** (± se deg) | 1.6 | 0.5 | 0.8 ± 1.61 | 17.5 | 0.0 | 2.2 ± 2.98 |
| Min. | -0.8 | -8.4 | -8.4 | | -11.2 | -11.2 |
| Max. | 2.8 | 8.4 | 8.4 | | 8.3 | 17.5 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se deg) | 1.4 | 5.5 | 3.5 ± 2.05 | 5.2 | -1.0 | 2.1 ± 3.1 |
| **T2-T3** | -1.7 | -1.2 | -1.5 ± 0.25 | 13.5 | 0.7 | 7.1 ± 6.4 |
| **T3-T4** | 3.0 | -5.8 | -1.4 ± 4.4 | -1.2 | 1.3 | 0.1 ± 1.25 |
| **T4-T5** | 2.5 | -1.6 | 0.5 ± 2.05 | 0.8 | -1.4 | -0.3 ± 1.1 |
| **T1-T5** | 5.2 | -3.1 | 1.1 ± 4.15 | 18.3 | -0.4 | 9.0 ± 9.35 |

* = $P < 0.05$
** = $P < 0.005$

The seven females showed minimal change for all periods. The mean change between T1 and T4 was 0.5°. The long term male subject did not change significantly at surgery or during the first six weeks. Small increases were measured from T3-T4 (3.0°) and T4-T5 (2.5°) which were not significant. The female patient increased interincisal angle by 5.5° suggesting an anticlockwise rotation of the mandible. This decreased a similar amount (-5.8°) between T3-T4. No significant change occurred between T4 and T5.

*Group 2: BSSA & LFI screws (N = 8; Table 7.19)*

The interincisal angle increased a mean 4.7° ($P < 0.05$) at surgery. A change of -3.5° occurred between T3-T4 but this was not significant. The long term female patient showed minimal change for all intervals. The male however, had an increase at surgery of 5.2° and a large increase (13.5°) between T2-T3. No significant changes subsequently occurred but the net change was 18.3° compared to the preoperative figure.

*Group 3: BSSA wire (N = 12; Table 7.20)*

The interincisal angle did not alter significantly with surgery or at T3. An increase of 3.1° at T4 was not significant. The net effect at 12 months was a non-significant increase of 3.1 ± 1.99°. The eight females in the group averaged minimal changes throughout and registered a non-significant change of 1.6°. An average net gain (T1-T4) of 6.3 ± 0.26° was recorded for the four males but this was not significant. None of the differences between sexes were significant. The nine long term patients underwent minor postsurgical changes providing a long term increase of 3.7 ± 2.11° (R: -8.2 - 11.4°).

*Group 4: BSSA & LFI wire (N = 10; Table 7.20)*

The mean interincisal angle did not change at surgery or at T3. Post-fixation changes (T3-T4) were recorded (-3.2 ± 2.92°) but were not significant. The seven females in this group initially increased 4.6° at operation and decreased -3.2° between T3 and T4. None of the changes were significant. In the long term, the seven patients did not change significantly after 2 years although there was wide individual variation (R: -12.1 - 9.5°).

**Table 7.20: Changes in interincisal angle for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 4** | **F: 8** | **Total: 12** | **M: 3** | **F: 7** | **Total: 10** |
| **T1-T2** (± se deg) | -0.2 | 1.2 | 0.7 ± 1.24 | -3.3 | 4.6 | 0.0 ± 1.93 |
| *t*-value | 0.07 | 0.74 | 0.04 | 1.00 | 0.65 | 0.02 |
| Min. (deg) | -6.4 | -4.6 | -6.4 | -1.7 | -1.7 | -3.3 |
| Max. (deg) | 4.1 | 8.1 | 8.1 | 9.6 | 11.7 | 9.6 |
| **T2-T3** (± se deg) | 2.0 | -1.0 | 0.1 ± 1.78 | -2.3 | -1.0 | 0.8 ± 1.33 |
| *t*-value | 0.43 | 0.76 | 0.04 | 1.11 | 2.20 | 0.60 |
| Min. | -9.7 | -6.6 | -9.7 | -6.3 | -4.1 | -6.3 |
| Max. | 12.3 | 4.7 | 12.3 | 0.4 | 2.4 | 5.4 |
| **T3-T4** (± se deg) | 4.4 | 2.3 | 3.1 ± 1.99 | -5.3 | -3.9 | -3.2 ± 2.92 |
| *t*-value | 1.11 | 0.99 | 1.56 | 0.79 | 0.62 | 1.09 |
| Min. | -2.2 | -6.6 | -6.6 | -14.5 | -13.7 | -14.5 |
| Max. | 15.2 | 7.8 | 15.2 | 7.8 | 2.0 | 7.8 |
| **T1-T4** (± se deg) | 6.3 | 1.6 | 3.2 ± 1.96 | -4.2 | 0.0 | 0.8 ± 2.28 |
| Min. | 1.9 | -7.6 | -7.6 | -11.2 | -11.2 | -11.2 |
| Max. | 9.9 | 11.4 | 11.4 | 5.2 | 8.3 | 9.6 |
| **Long term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se deg) | -0.8 | 0.5 | 0.0 ± 1.38 | -1.7 | -1.4 | -1.4 ± 2.29 |
| **T2-T3** | 2.3 | -0.2 | 0.8 ± 2.31 | -0.9 | 2.5 | 1.8 ± 1.38 |
| **T3-T4** | 6.2 | 3.2 | 4.3 ± 2.31 | 7.8 | -2.8 | -0.6 ± 3.58 |
| **T4-T5** | -2.2 | 0.7 | -0.3 ± 1.20 | -1.6 | -0.3 | -0.5 ± 1.75 |
| **T1-T5** | 5.4 | 2.8 | 3.7 ± 2.11 | 3.6 | 0.9 | 1.3 ± 2.69 |
| Min. | -0.3 | -8.2 | -8.2 | | -12.1 | -12.1 |
| Max. | 8.4 | 11.4 | 11.4 | | 9.5 | 9.5 |

### 7.4.3. *Lower incisal angle (GoMe-IIAI)*

*Group 1: BSSA screws (N = 10; Table 7.21)*

The mean of the lower incisal angle varied little from one period to the next. For the male group, the mean of the lower incisal angle did not alter appreciably between T1-T2. Small fluctuations in the mean at T3 and T4 were measured but individual variation was apparent. There were no significant mean changes in the female group for any period. For the two long term cases, the mean variation in the lower incisal angle was similar to the intermediate group.

*Group 2: BSSA & LFI screws (N = 8; Table 7.21)*

The mean change in the lower incisal angle was minimal in this group. The female patients averaged a small increase in each period following surgery but the mean change from T1 to T4 was 2.4°.

In the long term, the male had quite a pronounced shift between T2 and T3 (-7.6°). Smaller changes occurred over subsequent intervals. Net retraction from T1 to T5 was -12.3°. The female patient also changed at T3 (-5.2°) but the magnitude of the change was less. Minor changes were recorded at T5 giving a net change of -4.0°.

**Table 7.21: Changes in lower incisal angle for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 3** | **F: 7** | **Total: 10** | **M: 1** | **F: 7** | **Total: 8** |
| **T1-T2** (± se deg) | 1.2 | 0.1 | 0.4 ± 0.71 | -0.8 | 0.0 | -0.1 ± 0.99 |
| *t*-value | 2.60 | 0.12 | 0.62 | | 0.01 | 0.11 |
| Min. (deg) | 0.4 | -3.8 | -3.8 | | -3.0 | -3.0 |
| Max. (deg) | 2.0 | 3.5 | 3.5 | | 6.2 | 6.2 |
| **T2-T3** (± se deg) | -1.4 | -0.2 | -0.6 ± 1.16 | -7.6 | 1.7 | 0.4 ± 1.83 |
| *t*-value | 0.65 | 0.21 | 0.59 | | 1.13 | 0.20 |
| Min. | -5.7 | -3.7 | -5.7 | | -5.2 | -7.6 |
| Max. | 0.8 | 5.4 | 5.4 | | 4.8 | 4.8 |
| **T3-T4** (± se deg) | -1.2 | -0.3 | -0.9 ± 0.88 | -2.0 | 1.2 | 0.8 ± 1.59 |
| *t*-value | 0.50 | 0.39 | 0.68 | | 0.68 | 0.48 |
| Min. | -5.3 | -3.4 | -5.3 | | -5.4 | -5.4 |
| Max. | 2.8 | 2.4 | 2.8 | | 7.6 | 7.6 |
| **T1-T4** (± se deg) | -1.4 | -0.5 | -0.7 ± 0.95 | -10.4 | 2.4 | 0.8 ± 2.58 |
| Min. | -3.3 | -6.4 | -6.4 | | -5.6 | -10.4 |
| Max. | 0.1 | 4.8 | 4.8 | | 11.3 | 11.3 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se deg) | 1.4 | 5.5 | 0.6 ± 0.15 | -0.8 | -0.4 | -0.6 ± 0.2 |
| **T2-T3** | -1.7 | -1.2 | 0.0 ± 0.70 | -7.6 | -5.2 | -6.4 ± 1.2 |
| **T3-T4** | 3.0 | -5.8 | 0.7 ± 1.70 | -2.0 | 1.6 | -0.2 ± 1.80 |
| **T4-T5** | 2.5 | 2.2 | 0.2 ± 2.00 | -1.9 | 0.0 | -1.0 ± 0.95 |
| **T1-T5** | -1.7 | 4.6 | 1.5 ± 3.15 | -12.3 | -4.0 | -8.2 ± 4.15 |

*Group 3: BSSA wire (N = 12; Table 7.22)*

The lower incisal angle decreased -5.2 ± 1.50° ($P < 0.005$) following surgery and increased slightly at six weeks (2.3 ± 1.91°). A significant ($P < 0.05$) difference (-5.5 ± 1.58°) between the preoperative and T4 postoperative angle was recorded. The female patients showed a significant ($P < 0.05$) change at surgery (-4.9°) but none of the later changes differed at the 5% level. Males averaged -6.0° at surgery and recorded a significant reduction at 12 months (-9.8°; $P < 0.05$). The nine long term patients recorded a significant ($P < 0.05$) change between T1-T2 (5.0 ± 1.66°) and T1-T5 (-5.3 ± 1.70°).

**Table 7.22: Changes in lower incisal angle for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M: 4** | **F: 8** | **Total: 12** | **M: 3** | **F: 7** | **Total: 10** |
| **T1-T2** (± se deg) | -6.0 | -4.9 | -5.2 ± 1.50 | -3.3 | 4.6 | -1.8 ± 1.04 |
| *t*-value | 1.97 | 2.69* | 3.50** | 1.13 | 1.26 | 1.74 |
| Min. (deg) | -13.1 | -13.8 | -13.8 | -8.0 | -1.7 | -8.0 |
| Max. (deg) | 1.0 | 2.9 | 2.9 | 2.1 | 11.7 | 2.5 |
| **T2-T3** (± se deg) | 4.1 | 1.2 | 2.3 ± 1.91 | 2.6 | -1.0 | -0.7 ± 1.45 |
| *t*-value | 0.99 | 0.60 | 1.18 | 1.82 | 1.67 | 0.48 |
| Min. | -3.1 | -5.2 | -5.2 | 0.2 | -4.1 | -6.3 |
| Max. | 12.1 | 11.8 | 12.1 | 5.2 | 2.4 | 5.2 |
| **T3-T4** (± se deg) | -7.9 | 0.4 | -2.6 ± 2.01 | -2.8 | -3.9 | 0.0 ± 1.61 |
| *t*-value | 2.69 | 0.19 | 1.31 | 1.06 | 0.87 | 0.02 |
| Min. | -14.3 | -6.4 | -14.3 | -7.8 | -13.7 | -7.8 |
| Max. | -0.8 | 7.5 | 7.5 | 0.9 | 2.0 | 8.5 |
| **T1-T4*** (± se deg) | -9.8* | -3.3 | -5.5 ± 1.58* | -3.5 | -4.9 | -4.5 ± 1.75* |
| Min. | -12.4 | -9.6 | -12.4 | -5.5 | -19.1 | -19.1 |
| Max. | -7.5 | 4.4 | 4.4 | -0.7 | 0.7 | 0.7 |
| **Long term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se deg) | -6.8 | -4.1 | 5.0 ± 1.66 | 2.1 | -1.0 | -0.6 ± 1.01 |
| **T2-T3** | 6.4 | -0.6 | 2.1 ± 2.22 | 0.2 | -4.0 | -3.1 ± 1.32 |
| **T3-T4** | -10.3 | 1.4 | -3.0 ± 2.68 | 7.8 | 2.7 | 0.6 ± 2.58 |
| **T4-T5** | 3.1 | -0.9 | 0.4 ± 1.24 | 1.0 | 1.7 | 1.6 ± 1.14 |
| **T1-T5*** | -7.5* | -4.2 | -5.3 ± 1.70* | -4.5 | -3.7 | -3.8 ± 2.04 |
| Min. | -9.4 | -14.8 | -14.8 | | -14.1 | -14.1 |
| Max. | -5.1 | 1.7 | 1.7 | | 3.3 | 3.3 |

* = $P < 0.05$
** = $P < 0.005$

*Group 4: BSSA & LFI wire (N = 10; Table 7.22)*

The mean of the lower incisal angle did not vary much for any of the intervals. However, a significant ($P < 0.05$) difference existed between T1 and T4 (-4.5 ± 1.75°). The females in this group did not have any significant changes although one patient had a change of -19.1° between T1-T4. The seven long term patients did not differ significantly for any of the periods and at 24 months had a mean net change of -3.8°.

### 7.4.4. *Overjet (IS-II)*

*Group 1: BSSA screws (N = 10; Table 7.23)*

Overjet was significantly ($P < 0.005$) reduced at surgery with a mean value of -4.9 ± 0.37 mm (R: -3.2 - -6.5 mm). No significant changes were recorded at subsequent postsurgical intervals. Females and males showed very similar reductions in overjet at each interval for both the intermediate and long term subsets.

*Group 2: BSSA & LFI screws (N = 8; Table 7.23)*

A reduction in overjet of -6.7 ± 1.06 mm was recorded for this group with a range from -2.9 to -11.6 mm. There was no significant change following surgery resulting in a net change of -6.3 mm. As in Group 1, the intermediate and long term groups showed similar changes in magnitude.

**Table 7.23: Changes in overjet for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M:3** | **F:7** | **Total:10** | **M:1** | **F:7** | **Total:8** |
| **T1-T2** (± se mm) | -5.0 | -4.7 | -4.9 ± 0.37 | -5.8 | -6.8 | -6.7 ± 1.06 |
| *t*-value | 5.36* | 15.30** | 14.85** | | 5.62** | 6.32** |
| Min. (mm) | -6.5 | -5.7 | -6.5 | | -11.6 | -11.6 |
| Max. (mm) | -3.3 | -3.2 | -3.2 | | -2.9 | -2.9 |
| **T2-T3** (± se mm) | -0.7 | 0.2 | -0.1 ± 0.54 | 2.0 | -0.3 | 0.1 ± 1.05 |
| *t*-value | 0.42 | 0.65 | 0.13 | | 0.07 | 0.21 |
| Min. | -3.7 | -1.1 | -3.7 | | -5.4 | -5.4 |
| Max. | 1.7 | 1.2 | 1.7 | | 2.5 | 2.5 |
| **T3-T4** (± se mm) | 1.1 | 0.2 | 0.5 ± 0.47 | 1.6 | -0.3 | 0.0 ± 0.58 |
| *t*-value | 1.14 | 0.42 | 1.11 | | 0.47 | 0.03 |
| Min. | -0.1 | -1.0 | -1.0 | | -2.0 | -2.0 |
| Max. | 3.1 | 2.2 | 3.1 | | 2.1 | 2.1 |
| **T1-T4**** (± se mm) | -4.5 | -4.3 | -4.3 ± 0.45 | -2.2 | -6.9 | -6.3 ± 1.16 |
| Min. | -4.9 | -6.0 | -6.0 | | -12.4 | -12.4 |
| Max. | -3.9 | -2.8 | -2.8 | | -2.9 | -2.2 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se mm) | -5.1 | -5.7 | -5.4 ± 0.30 | 3.8 | -2.9 | 4.4 ± 1.45 |
| **T2-T3** | 0.0 | 0.2 | 0.1 ± 0.20 | 0.8 | 1.3 | 1.7 ± 0.35 |
| **T3-T4** | 0.4 | 0.0 | 0.2 ± 0.20 | 0.6 | -1.3 | 0.2 ± 1.45 |
| **T4-T5** | 0.0 | 0.4 | 0.2 ± 0.20 | -0.1 | -0.3 | 0.1 ± 0.35 |
| **T1-T5** | -4.7 | -5.1 | -4.9 ± 0.20 | 5.1 | -3.2 | -2.5 ± 0.70 |

* = $P < 0.05$
** = $P < 0.005$

*Group 3: BSSA wire (N = 12; Table 7.24)*

Overjet was reduced a mean of -5.6 ± 0.79 mm at surgery. A mean increase during T3-T4 (1.1 ± 0.46 mm) was statistically significant ($P < 0.05$). A net reduction in overjet of -4.4 mm was measured (T1-T4). Female patients had a statistically significant ($P < 0.05$) reduction in overjet of -5.4 mm at T2. None of the subsequent changes were statistically significant. The male patients did not alter significantly during the period of observation.

Nine long term cases had a reduction in overjet of -6.3 ± 0.91 mm. Mean increases of 1.4 mm at T4 and at T5 of 1.1 mm were observed but these were not significant.

**Table 7.24: Changes in overjet for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M:4** | **F:8** | **Total:12** | **M:3** | **F:7** | **Total:10** |
| **T1-T2** (± se mm) | -6.0 | -5.4 | -5.6 ± 0.79 | -4.5 | -5.2 | -5.0 ± 0.68 |
| *t*-value | 3.05 | 6.94** | 7.15** | 3.49 | 6.13* | 7.36** |
| Min. (mm) | -11.8 | -7.8 | -11.8 | -7.0 | -7.9 | -7.9 |
| Max. (mm) | -3.3 | -1.8 | -1.8 | -2.9 | -2.2 | -2.2 |
| **T2-T3** (± se mm) | 0.8 | -0.3 | 0.1 ± 0.31 | -1.1 | -0.3 | -0.6 ± 0.45 |
| *t*-value | 2.65 | 0.80 | 0.26 | 0.92 | 1.18 | 1.37 |
| Min. | 0.1 | -0.2 | -2.0 | -3.5 | -1.3 | -3.5 |
| Max. | 1.4 | 1.1 | 1.4 | 0.1 | 0.3 | 0.3 |
| **T3-T4** (± se mm) | 0.9 | 1.3 | 1.1 ± 0.46 | 2.5 | 0.5 | 1.3 ± 0.59 |
| *t*-value | 1.18 | 2.15 | 2.54* | 2.47 | 1.00 | 2.18 |
| Min. | -0.7 | -0.1 | -0.7 | 0.6 | -1.1 | -1.1 |
| Max. | 2.9 | 3.5 | 3.5 | 4.1 | 1.5 | 4.1 |
| **T1-T4**** (± se mm) | -4.3 | -4.4 | -4.4 ± 0.83 | -3.0 | -4.5 | -4.0 ± 0.53 |
| Min. | -11.1 | -7.1 | -11.1 | -4.0 | -5.9 | -5.9 |
| Max. | -0.4 | -1.9 | -0.4 | -2.3 | -0.9 | -0.9 |
| **Long term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se mm) | -6.3 | -6.3 | -6.3 ± 0.91 | -3.5 | -2.9 | -4.7 ± 0.82 |
| **T2-T3** | 0.7 | 0.0 | 0.3 ± 0.29 | 0.1 | 1.3 | -0.4 ± 0.25 |
| **T3-T4** | 0.8 | 1.7 | 1.4 ± 0.60 | 0.6 | -1.3 | 0.4 ± 0.49 |
| **T4-T5** | 2.1 | 0.5 | 1.1 ± 0.55 | 1.9 | -0.3 | 0.8 ± 0.48 |
| **T1-T5*** | -2.7 | -4.0 | -3.6 ± 1.13 | -0.9 | -3.2 | -3.3 ± 0.81 |
| **Min** | -7.3 | -7.6 | -7.6 | | -6.1 | -6.1 |
| **Max** | 0.8 | 0.6 | 0.8 | | 0.9 | 0.9 |

* = $P < 0.05$
** = $P < 0.005$

*Group 4: BSSA & LFI wire (N = 10; Table 7.24)*

A significant reduction in overjet (-5.0 ± 0.68 mm) occurred at surgery. None of the changes in the following periods were statistically significant. The female group recorded a significant ($P < 0.05$) reduction of -5.2 mm at T2 and were left with a net value of -4.5 mm at 12 months.

Seven patients in the long term category changed a mean -4.7 ± 0.82 mm at surgery. There were no changes of significance in the postsurgical phase. The net change from T1 to T5 was -3.3 mm.

### *7.4.5. Overbite (IS-II)*

<u>*Group 1: BSSA screws (N = 10; Table 7.25)*</u>

A mean reduction in overbite of -3.3 ± 0.58 mm was measured following surgery. A significant ($P < 0.05$) increase between T3 and T4 was measured (1.3 ± 0..59 mm) producing a net change of -1.2 mm. The males and females recorded reductions of -3.2 mm and -3.3 mm respectively. Neither group changed significantly in the postoperative period.

For the 2 long term cases, the male decreased -3.3 mm at operation but increased 2.4 mm within six weeks. No changes occurred at T4 or T5. The net reduction from surgery was -0.5 mm. The female decreased -2.4 mm at T2 and regained 1.4 mm in the intermediate period. A net reduction of -1.5 mm was measured two years after surgery.

**Table 7.25: Changes in overbite for bilateral sagittal split advancement (BSSA) with screw fixation.**

| GROUP | 1: BSSA SF | | | 2: LFI & BSSA SF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M:3** | **F:7** | **Total:10** | **M:1** | **F:7** | **Total:8** |
| **T1-T2** (± se mm) | -3.2 | -3.3 | -3.3 ± 0.39 | 1.8 | -1.5 | -1.1 ± 1.62 |
| *t*-value | 3.16 | 8.04** | 8.54** | | 0.81 | 0.66 |
| Min. (mm) | -4.9 | -4.9 | -4.9 | | -7.2 | -7.2 |
| Max. (mm) | -1.4 | -2.1 | -1.4 | | 5.4 | 5.4 |
| **T2-T3** (± se mm) | 0.8 | 0.8 | 0.1 ± 0.42 | 0.5 | 1.1 | 1.0 ± 0.44 |
| *t*-value | 0.84 | 1.69 | 1.97 | | 2.07 | 2.23 |
| Min. | -1.0 | -0.7 | -1.0 | | -0.2 | -0.2 |
| Max. | 2.4 | 3.0 | 3.0 | | 3.4 | 3.4 |
| **T3-T4** (± se mm) | 1.5 | 1.3 | 1.3 ± 0.59 | -1.8 | 1.0 | 0.6 ± 0.50 |
| *t*-value | 1.2 | 1.77 | 2.27* | | 2.70* | 1.15 |
| Min. | 0.2 | -2.1 | -2.1 | | 0.0 | -1.8 |
| Max. | 4.0 | 3.9 | 4.0 | | 2.3 | 2.3 |
| **T1-T4**** (± se mm) | -0.9 | -1.2 | -1.2 ± 0.26 | 0.5 | -0.3 | -0.2 ± 1.01 |
| Min. | -1.9 | -2.2 | -2.2 | | -4.1 | -4.1 |
| Max. | -0.1 | 0.0 | 0.0 | | 4.1 | 4.1 |
| **Long term** | **M: 1** | **F: 1** | **Total: 2** | **M: 1** | **F: 1** | **Total: 2** |
| **T1-T2** (± se mm) | -3.3 | -2.4 | -2.9 ± 0.45 | 1.8 | -6.5 | 2.4 ± 4.15 |
| **T2-T3** | 2.4 | 0.3 | 1.4 ± 1.10 | 0.5 | 3.4 | 2.0 ± 1.45 |
| **T3-T4** | 0.3 | 1.1 | 0.7 ± 0.40 | -1.8 | 0.0 | -0.9 ± 0.90 |
| **T4-T5** | 0.1 | -0.5 | 0.2 ± 0.30 | -1.6 | 0.6 | -0.5 ± 1.10 |
| **T1-T5** | -0.5 | -1.5 | -1.0 ± 0.50 | -1.1 | -2.5 | -1.8 ± 0.70 |

* = $P < 0.05$
** = $P < 0.005$

*Group 2: BSSA & LFI screws (N = 8; Table 7.25)*

The mean reduction in overbite of -1.1 ± 1.62 mm increased 1.2 ± 0.44 mm at T3 and 0.6 ± 0.50 mm at T4. None of these changes were significant. The net change 12 months after surgery was -0.2 ± 1.01 mm. Seven females showed reductions in overbite of -1.5 mm. A significant ($P < 0.05$) increase of 1.3 mm was measured at T4.

The one long term male in this group decreased -3.3 mm at surgery but there was an increase of 2.4 mm at T3. This resulted in a net change of -0.5 mm 24 months after surgery. The long term female had a surgical reduction of -2.4 mm. Overbite increased between T3 and T4 (1.1 mm) giving a net reduction of -1.5 mm.

*Group 3: BSSA wire (N = 12; Table 7.26)*

A mean decrease of -4.2 ± 0.60 mm was recorded for this group at surgery. A significant ($P < 0.05$) increase was measured in the 12 month period (2.1 mm). This gave a net average reduction of -1.3 mm with a range from 0.7 - -3.5 mm. The four males in group 3 decreased a mean -4.8 ± 0.78 mm. None of the postoperative changes were significant but the increase between T3 and T4 was relatively large (2.1 mm). The net reduction was -2.2 mm twelve months after surgery. Females (N = 8) decreased a mean -3.9 mm. As for the males, no significant change was recorded postsurgically although a relatively large movement occurred between T3 and T4.

The nine long term patients had an average surgical reduction of -4.0 ± 0.76 mm. A significant ($P < 0.05$) change at T3-T4 was observed resulting in an increase in overbite of 2.1 ± 0.64 mm. This gave a net change of -1.4 ± 0.71 mm.

**Table 7.26: Changes in overbite for bilateral sagittal split advancement (BSSA) with wire fixation.**

| GROUP | 3: BSSA WF | | | 4: LFI & BSSA WF | | |
|---|---|---|---|---|---|---|
| **Patients** | **M:4** | **F:8** | **Total:12** | **M:3** | **F:7** | **Total:10** |
| T1-T2 (± se mm) | -4.8 | -3.9 | -4.2 ± 0.60 | -5.1 | -2.6 | -3.4 ± 0.97 |
| *t*-value | 3.75* | 5.86* | 7.07* | 3.04 | 2.28 | 3.46* |
| Min. (mm) | -8.6 | -6.5 | -8.6 | -7.0 | -6.1 | -7.0 |
| Max. (mm) | -3.0 | -0.7 | -0.7 | -1.8 | -1.3 | -1.3 |
| T2-T3 (± se mm) | 0.5 | 0.5 | 0.5 ± 0.37 | 0.8 | 1.4 | 1.1 ± 0.39 |
| *t*-value | 1.83 | 0.86 | 1.34 | 0.88 | 3.30* | 2.92* |
| Min. | -0.1 | -1.8 | -1.8 | -0.2 | 0.5 | -0.2 |
| Max. | 1.2 | 3.0 | 3.0 | 2.4 | 2.5 | 2.5 |
| T3-T4 (± se mm) | 2.1 | 2.0 | 2.1 ± 0.61 | 1.8 | 0.1 | 0.7 ± 0.55 |
| *t*-value | 2.30 | 2.35 | 3.37* | 2.67 | 0.20 | 1.34 |
| Min. | 0.4 | 0.0 | 0.0 | 0.6 | -1.8 | -1.8 |
| Max. | 3.9 | 5.5 | 5.5 | 2.7 | 2.1 | 2.7 |
| T1-T4** (± se mm) | -2.2 | -1.3 | -1.6 ± 0.42 | -2.7 | -1.1 | -1.5 ± 0.78 |
| Min. | -3.5 | -3.5 | -3.5 | -4.6 | -4.6 | -4.6 |
| Max. | -0.3 | 0.7 | 0.7 | -1.5 | 2.7 | 2.7 |
| **Long term** | **M: 3** | **F: 6** | **Total: 9** | **M: 1** | **F: 6** | **Total: 7** |
| **T1-T2** (± se mm) | -5.1 | -3.5 | -4.0 ± 0.76 | -7.0 | -2.5 | -3.1 ± 1.31 |
| **T2-T3** | 0.6 | 0.5 | 0.5 ± 0.26 | 2.4 | 1.6 | 1.7 ± 0.39* |
| **T3-T4** | 2.6 | 1.7 | 2.1 ± 0.64 | 2.7 | 0.1 | 0.6 ± 0.87 |
| **T4-T5** | 0.6 | -0.3 | 0.0 ± 0.37 | -1.6 | 0.1 | -0.1 ± 0.49 |
| **T1-T5*** | -1.3 | -1.5 | -1.4 ± 0.71 | -3.5 | -0.7 | -1.1 ± 0.74 |
| **Min** | -7.3 | -7.6 | -7.6 | | -6.1 | -6.1 |
| **Max** | 0.8 | 0.6 | 0.8 | | 0.9 | 0.9 |

* = $P < 0.05$
** = $P < 0.005$

*Group 4: BSSA & LFI wire (N = 10; Table 7.26)*

The average reduction in overbite was -3.4 ± 0.97 mm with a range of -1.3 to -7.0 mm. At T3, there was a significant increase of 1.1 ± 0.39 mm. A net value of -1.5 mm was averaged for the 10 cases at 12 months. Neither the female or male subsets achieved statistically significant changes at surgery. The female sample increased overbite significantly at T3 (1.4 mm). The long term cases decreased -3.1 mm at surgery. The change at T3 achieved statistical significance and left a net reduction in overbite of -1.1 ± 0.74 mm two years after surgery.

# CHAPTER 8

## RESULTS
## ANALYSIS OF VARIABLES BY METHOD OF FIXATION

The two subsets within the screw and wire fixation groups were compared for preoperative (T1) and immediate postoperative (T2) differences by Student's *t*-test for unpaired values. No significant differences ($P < 0.05$) were found for the thirteen variables between subsets for either period. Therefore groups 1 and 2 (screw fixation) were combined and subsequently compared to groups 3 and 4 (wire fixation).

### *8.1. MANDIBULAR MOVEMENT*

#### *8.1.1. Horizontal advancement and relapse (Table 8.1)*

*Screw fixation (N = 18)*

A mean advancement of 5.4 ± 0.54 mm was measured for the eighteen patients at surgery. There was early return of -1.1 mm at six weeks and a further -0.9 mm at 12 months. This left a net gain of 3.2 ± 0.40 mm. For the long term patients, no relapse was recorded in the second year leaving a net gain of 4.0 mm.

*Wire fixation (N = 22)*

Twenty-two patients had a mean increase of 5.9 ± 0.64 mm at surgery. Mean losses of -0.8 mm for both T3 and T4 resulted in a net increase in mandibular length of 4.4 ± 0.57 mm after 12 months. The long term patients did not change on average and 3.7 mm was maintained after 24 months.

**Table 8.1: Relapse patterns (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | **18** | **22** |
| **T1-T2** | 5.4 ± 0.54 | 5.9 ± 0.64 |
| **T2-T3** | -1.1 ± 0.45 | -0.8 ± 0.40 |
| **T3-T4** | -0.9 ± 0.37 | -0.8 ± 0.38 |
| **T2-T4** | -2.0 ± 0.40 | -1.6 ± 0.47 |
| **T1-T4** | 3.2 ± 0.53 | 4.4 ± 0.57 |
| **% Relapse** | | |
| **T2-T3** | -20.3 | -13.6 |
| **T3-T4** | -16.7 | -13.6 |
| **T2-T4** | -37.0 | -27.2 |
| **Patients** | **4** | **16** |
| **T4-T5** | 0.0 ± 0.48 | 0.1 ± 0.25 |
| **T1-T5** | 4.0 ± 1.80 | 3.7 ± 0.72 |
| **% Relapse** | | |
| **T4-T5** | 0.0 | +1.7 |

No statistically significant difference between screw and wire fixation.

### *8.1.2. Angle SNB (Table 8.2)*

*Wire and Screw fixation*

Both groups underwent similar operative and postoperative changes and no statistical difference was demonstrated. The 18 patients secured with screw fixation had an average SNB increase of 3.4°. Between T2 and T4, -1.4 ± 0.22° was lost giving a net increase of 2.0° at T4. The long term patients had a net increase of 2.3° at T5.

Following surgery, the wire fixation group had an increase in SNB of 3.9 ± 0.32°. Small losses at T3 and T4 left a net gain of 2.7° at T4. The long term patients had a net gain of 2.5° at T5.

**Table 8.2: Changes in SNB (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | **18** | **22** |
| **T1-T2** | 3.4 ± 0.26 | 3.9 ± 0.32 |
| **T2-T3** | -0.7 ± 0.26 | -0.6 ± 0.20 |
| **T3-T4** | -0.6 ± 0.19 | -0.7 ± 0.21 |
| **T2-T4** | -1.4 ± 0.22 | -1.2 ± 0.23 |
| **T1-T4** | 2.0 ± 0.24 | 2.7 ± 0.30 |
| **Patients** | **4** | **16** |
| **T1-T5** | 2.3 ± 0.86 | 2.5 ± 0.40 |

No significant difference between screw and wire fixation.

## *8.2. PROXIMAL AND DISTAL SEGMENT ALTERATION*

### 8.2.1. *Condylar displacement (Table 8.3)*

*Screw fixation (N = 18)*

The screw fixation group had an average increased gonial arc (HA-Go) of 1.3 ± 0.44 mm at T2 which decreased -1.1 ± 0.46 mm at T3. Minor shifts occurred at T4 (0.1 ± 0.51 mm) and T5 (-1 ± 0.83 mm). Differences were observed in surgically altered gonial arc radius (T2) between sexes (F: 1.8 mm; M:-0.5 mm; $P < 0.05$; DF = 16). None of the other periods were statistically significant.

*Wire fixation (N = 22)*

The wire fixation group showed a mean increase of 1.4 ± 0.42 mm at surgery and subsequent decrease of -1.6 ± 0.52 mm in the first six weeks. Mean changes of -0.9 mm and 0.2 mm were recorded at T4 and T5. Statistically significant differences were not shown between sexes except for T5 (F: -0.2 mm; M: 1.5 mm; $P < 0.05$; DF = 14). No statistically significant difference was shown when the screw and wire fixation groups were compared by Student's *t*-test for unpaired values.

**Table 8.3: Changes in gonial arc radius (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | 18 | 22 |
| **T1-T2** | 1.3 ± 0.44 | 1.4 ± 0.42 |
| **T2-T3** | -1.1 ± 0.46 | -1.6 ± 0.52 |
| **T3-T4** | 0.1 ± 0.51 | -0.9 ± 0.46 |
| **T2-T4** | -1.3 ± 0.47 | -2.2 ± 0.49 |
| **T1-T4** | 0.0 ± 0.36 | -0.1 ± 0.30 |
| **T4-T5** | -1.0 ± 0.83 | 0.2 ± 0.34 |
| **Patients** | 4 | 16 |
| **T1-T5** | -0.5 ± 0.67 | -0.4 ± 0.39 |

No significant difference between screw and wire fixation.

To assess whether altered gonial arc radius contributed to relapse, patients were divided into two groups (Table 8.4). A value of 0.4 mm was chosen for demarcation as this was the limit of measurement error found in the error study. Twenty-one patients had gonial arc changes less than 0.4 mm with a mean of -0.1 ± 0.20 mm (R: -2.2 - 1.1). This group was advanced a mean distance of 4.9 mm at B point and relapsed -16.3%. The remaining nineteen patients had gonial arc changes ranging from 1.2 - 5.5 mm with a mean of 2.9 ± 0.32 mm. Movement at B point measured 6.5 mm at T2 and -1.2 mm or -18.5% at T3. The groups did not differ significantly at the 1% level when compared using Student's *t*-test ($P$ = 0.534). This pattern was maintained irrespective of the method of fixation.

**Table 8.4: Contribution of altered gonial arc radius (GAR) at surgery (T1-T2) to relapse tendency during the early postoperative period (T2-T3).**

| Group | GAR T1-T2 | Mean GAR (mm) | Std. Error | Mean % Relapse | Unpaired *t*-value | *P* (2-tail) |
|---|---|---|---|---|---|---|
| *All patients* | | | | | | |
| 14 | ≤ 0.4 mm | -0.5 | 0.20 | -6.3 | 0.41 | 0.685 |
| 26 | > 0.4 mm | 2.4 | 0.30 | -11.9 | | |
| *Screw fixation* | | | | | | |
| 6 | ≤ 0.4 mm | -0.5 | 0.36 | -1.8 | 0.67 | 0.513 |
| 12 | > 0.4 mm | 2.2 | 0.43 | -16.6 | | |
| *Wire fixation* | | | | | | |
| 8 | ≤ 0.4 mm | -0.5 | 0.23 | -10.7 | 0.156 | 0.878 |
| 14 | > 0.4 mm | 2.5 | 0.43 | -7.9 | | |

### 8.2.2. *Posterior facial height (Table 8.5)*

*Screw fixation (N= 18)*

A mean increase of 0.6 ± 0.41 mm was measured for the subset. At the next interval, posterior facial height decreased -1.0 mm and changed minimally (0.04 mm) at T4. The resultant change following surgery (T2-T4) was a mean decrease of -1.1 ± 0.44 mm (R: -4.2 - 1.2 mm) giving a net change

(T1-T4) of 0.5 ± 0.30 mm (R: -3.4 - 1.4 mm). The four long term patients had a small decrease (-0.4 mm) in posterior facial height at surgery. Further shortening of -1.6 mm occurred at T3 but this returned at T4 with a mean increase of 1.5 mm. Shortening of 0.8 mm was measured at T5 giving a net decrease (T1-T5) in posterior facial height of -1.3 ± 0.48 mm (R: -2.7 - -0.6 mm).

*Wire fixation (N = 22)*

A mean increase in posterior facial height of 0.5 ± 0.40 mm resulted from surgery. This decreased -1.8 mm at T3 and a further -0.6 mm at T4. The mean change resulting from surgery was a shortening in posterior facial height of -1.7 ± 0.31 mm (R: -4.3 - 1.2 mm).

**Table 8.5: Changes in posterior facial height (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | **18** | **22** |
| **T1-T2** | 0.6 ± 0.41 | 0.5 ± 0.40 |
| **T2-T3** | -1.0 ± 0.41 | -1.8 ± 0.44 |
| **T3-T4** | 0.0 ± 0.44 | -0.6 ± 0.40 |
| **T2-T4** | -1.1 ± 0.44 | -1.7 ± 0.31 |
| **T1-T4** | -0.5 ± 0.30 | -1.7 ± 0.31 |
| **Patients** | **4** | **16** |
| **T4-T5** | -0.8 ± 0.76 | 0.3 ± 0.31 |
| **T1-T5** | -1.3 ± 0.48 | -1.1 ± 0.33 |

No significant difference between screw and wire fixation.

Changes for the 16 long term patients showed similar mean values as the intermediate (T4) group. Posterior facial height increased 0.5 mm at T2, decreased -1.8 mm at T3 and -0.5 mm at T4. A small mean gain was recorded at T5 of 0.3 ± 0.31 mm. The overall change in posterior facial height was -1.1 ± 0.33 mm (R: -3.0 - 1.6 mm).

### 8.2.3. *Anterior facial height (Table 8.6)*

*Screw fixation (N= 18)*

Anterior facial height increased a mean 4.3 ± 0.53 mm for the eighteen patients at surgery. This parameter shortened -1.1 mm at six weeks and a further -0.6 mm at 12 months. This left a net gain of 2.7 ± 0.47 mm (R: -1.0 - 6.5 mm).

*Wire fixation*

Twenty-two patients had a mean increase of 5.5 ± 0.66 mm at surgery. Mean losses of -1.4 mm (T3) and -1.7 mm (T4) resulted in a net increase in anterior facial height of 2.5 ± 0.64 mm after 12 months. The difference between the screw and wire groups was statistically significant at the 5% level for T3-T4 and T2-T4.

**Table 8.6: Changes in anterior facial height (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | 18 | 22 |
| **T1-T2** | 4.3 ± 0.53 | 5.5 ± 0.66 |
| **T2-T3** | -1.1 ± 0.37 | -1.4 ± 0.39 |
| **T3-T4** | -0.6 ± 0.31 | -1.7 ± 0.42* |
| **T2-T4** | -1.6 ± 0.50 | -3.0 ± 0.44* |
| **T1-T4** | 2.7 ± 0.47 | 2.5 ± 0.64 |
| **Patients** | 4 | 16 |
| **T4-T5** | 0.2 ± 0.24 | 0.3 ± 0.21 |
| **T1-T5** | 2.6 ± 1.39 | 3.2 ± 0.75 |

*Statistical difference ($P < 0.05$) between screw and wire fixation groups.

### 8.2.4. *Mandibular plane angle (Table 8.7)*

*Screw fixation (N= 18)*

Mandibular plane angle increased a mean 0.5 ± 0.64° for the eighteen patients at surgery. Minor changes occurred over the next 12 months. This left a net increase of 1.2 ± 0.63°.

*Wire fixation*

Twenty-two patients had a mean increase of 2.1 ± 0.58° at surgery. There was a mean increase of 1.0 ± 0.36° at the six week interval. An insignificant change of -0.5 ± 0.36° had occurred by one year (T4) equivalent to a change of -0.2 ± 0.41° between surgery and 12 months. The net effect compared to preoperative values was an increase in the mandibular plane angle of 2.3 ± 0.43° after 12 months. There was no statistically significant difference between the screw and wire groups for any of the periods.

**Table 8.7: Changes in mandibular plane angle (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | 18 | 22 |
| **T1-T2** | 0.5 ± 0.64 | 2.1 ± 0.58 |
| **T2-T3** | 0.4 ± 0.24 | 1.0 ± 0.36 |
| **T3-T4** | 0.0 ± 0.29 | -0.5 ± 0.36 |
| **T2-T4** | 0.7 ± 0.42 | -0.2 ± 0.41 |
| **T1-T4** | 1.2 ± 0.63 | 2.3 ± 0.43 |
| **Patients** | 4 | 16 |
| **T4-T5** | 0.4 ± 0.43 | 0.0 ± 0.27 |
| **T1-T5** | 1.8 ± 2.27 | 2.7 ± 0.61 |

No significant difference between screw and wire fixation.

To assess whether there was a relationship between preoperative mandibular plane angle and relapse pattern, the screw fixation group was subdivided into two subsets. Postsurgical relapse was compared between cases with normal mandibular plane angles and high mandibular plane angles (> 37°). A similar comparison was performed for the wire fixation group. Our data showed that high angle cases tended to have more relapse than low angle cases but none of these differences were statistically significant (Table 8.8).

**Table 8.8: The relationship between preoperative mandibular plane angle and relapse tendency.**

| All patients | SNGoMe T1 | Count | Mean % Relapse | Std. Error | Unpaired *t*-value | *P* (2-tail) |
|---|---|---|---|---|---|---|
| T2-T3 | < 37° | 26 | -6.2 | 7.13 | 0.965 | 0.342 |
| | > 37° | 10 | -19.9 | 13.70 | | |
| T2-T4 | < 37° | 28 | -24.7 | 6.77 | 0.840 | 0.407 |
| | > 37° | 12 | -34.8 | 9.47 | | |
| T2-T5 | < 37° | 16 | -36.3 | 11.69 | 0.590 | 0.560 |
| | > 37° | 4 | -21.4 | 16.68 | | |
| **Screw fixation** | | | | | | |
| T2-T3 | ≤ 37° | 12 | -2.0 | 13.30 | 1.46 | 0.165 |
| | > 37° | 5 | -33.9 | 10.05 | | |
| T2-T4 | ≤ 37° | 12 | -25.7 | 9.31 | 1.27 | 0.221 |
| | > 37° | 6 | -46.5 | 13.86 | | |
| **Wire fixation** | | | | | | |
| T2-T3 | ≤ 37° | 14 | -9.8 | 7.16 | 0.20 | 0.842 |
| | > 37° | 5 | -6.0 | 25.41 | | |
| T2-T4 | ≤ 37° | 16 | -23.9 | 9.73 | 0.05 | 0.959 |
| | > 37° | 6 | -23.0 | 12.13 | | |
| T2-T5 | ≤ 37° | 12 | -34.6 | 13.14 | 0.53 | 0.604 |
| | > 37° | 4 | -21.4 | 16.68 | | |

No significant differences between groups.

The sample was also compared by surgical procedure (Table 8.9). Although there was no significant difference, there appeared to be less relapse in the bimaxillary cases (Groups 3 and 4) independent of the method of fixation .

**Table 8.9: Comparison between high and low mandibular plane angle cases by surgical procedure.**

| High mandibular plane angle cases (> 37°) | | | | |
|---|---|---|---|---|
| Group | Number | SNGoMe T1 | Advancement (mm) | % Relapse |
| BSSA | | | | |
| 1 | 3 | 41.5 | 4.1 | -75.5 |
| 2 | 3 | 48.8 | 8.8 | -40.1 |
| LFI/BSSA | | | | |
| 3 | 2 | 38.5 | 6.1 | -27.5 |
| 4 | 4 | 43.8 | 8.4 | -20.8 |
| **Low mandibular plane angle cases (< 37°)** | | | | |
| Group | Number | SNGoMe T1 | Advancement (mm) | % Relapse |
| BSSA | | | | |
| 1 | 7 | 31.1 | 4.0 | -37.6 |
| 2 | 5 | 34.6 | 6.1 | -29.6 |
| LFI/BSSA | | | | |
| 3 | 10 | 30.8 | 5.4 | -34.9 |
| 4 | 6 | 33.6 | 5.0 | -9.3 |

No significant differences between groups.

## 8.3. SEGMENTAL INTER-RELATIONSHIPS

### 8.3.1. Gonial angle (Table 8.10)

*Screw fixation (N= 18)*

A mean increase in gonial angle of 4.0 ± 0.74° was measured at surgery. No significant changes occurred between T2 and T4. The resultant change following surgery (T2-T4) was a minor shift of 0.4 ± 0.51° giving a net change (T1-T4) of 4.4 ± 0.63°. Minor changes occurred in the long term patients but this change was not significant.

*Wire fixation (N = 22)*

A mean increase in gonial angle of 7.1 ± 0.71° resulted from surgery. This increased 1.7° at T3 and decreased -0.5° at T4. The net mean change resulting from surgery was an increase in gonial angle of 8.1 ± 0.81°. Significant differences were noted between the 2 groups at T1-T2 (*P* <0.005), T2-T3 (*P* <0.05) and T1-T4 (*P* <0.005). Changes for the 16 long term patients showed similar mean values as the intermediate (T4) group. A small mean reduction was recorded at T5 of -0.6 ± 0.43°. The overall change in gonial angle was 7.8 ± 0.84°.

**Table 8.10: Changes in gonial angle (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | 18 | 22 |
| **T1-T2** | 4.0 ± 0.74 | 7.1 ± 0.71** |
| **T2-T3** | 0.3± 0.35 | 1.7 ± 0.54* |
| **T3-T4** | 0.1 ± 0.36 | -0.5 ± 0.46 |
| **T2-T4** | 0.4 ± 0.51 | 1.0 ± 0.61 |
| **T1-T4** | 4.4 ± 0.63 | 8.1 ± 0.81** |
| **Patients** | 4 | 16 |
| **T4-T5** | -0.6 ± 0.17 | -0.6 ± 0.43 |
| **T1-T5** | 5.1 ± 0.50 | 7.8 ± 0.84 |

* = $P < 0.05$
** = $P < 0.005$
Significant difference between groups at T1-T2, T2-T3 and T1-T4.

### 8.3.2. *Ramal angle (Table 8.11)*

*Screw fixation (N= 18)*

The ramal angle decreased a mean -3.3 ± 0.63° for the eighteen patients at surgery. No significant changes were recorded over the next twelve months. This left a net reduction of -3.1 ± 0.49°. The ramal angle in the long term patients remained stable.

*Wire fixation*

Twenty-two patients had a mean reduction of -5.1 ± 0.85° at surgery. Small mean losses were recorded postsurgically resulting in a net reduction of -5.9 ± 0.84° after 12 months. The difference between the screw and wire groups was statistically significant at the 5% level for T1-T4. More anterosuperior rotation was observed for the wire fixation group at one year.

**Table 8.11: Changes in ramal angle (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | 18 | 22 |
| **T1-T2** | 4.3 ± 0.53 | 5.5 ± 0.66 |
| **T2-T3** | -1.1 ± 0.37 | -1.4 ± 0.39 |
| **T3-T4** | -0.6 ± 0.31 | -1.7 ± 0.42* |
| **T2-T4** | -1.6 ± 0.50 | -3.0 ± 0.44* |
| **T1-T4** | 2.7 ± 0.47 | 2.5 ± 0.64 |
| **Patients** | 4 | 16 |
| **T4-T5** | 0.2 ± 0.24 | 0.3 ± 0.21 |
| **T1-T5** | 2.6 ± 1.39 | 3.2 ± 0.75 |

*Statistical difference ($P < 0.05$) between screw and wire fixation groups.

## 8.4. DENTOSKELETAL CHANGES

### 8.4.1. Maxillary incisal angle (Table 8.12)

*Screw fixation (N= 18)*

The screw fixation group (N = 18) had an average decrease in maxillary incisal angle of -1.1 ± 0.71° at T2 which further retraction at T3 (-2.1 ± 0.89°). Postsurgical retraction occurred during T3-T4 (-1.2 ± 1.11°) resulting in a net reduction of -4.3°.

*Wire fixation*

The wire fixation group (N = 22) did not change significantly at surgery but decreased -1.7 ± 0.69° in the first six weeks. There were no statistically significant differences at each interval. However, a statistically significant difference ($P < 0.05$) was shown between the screw and wire fixation groups at T1-T4 when compared by Student's *t*-test for unpaired values.

**Table 8.12: Changes in maxillary incisal angle (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | 18 | 22 |
| **T1-T2** | -1.1 ± 0.71 | 0.8 ± 0.97 |
| **T2-T3** | -2.1 ± 0.89 | -1.7 ± 0.69 |
| **T3-T4** | -1.2 ± 1.11 | 0.7 ± 1.26 |
| **T2-T4** | -3.1 ± 0.90 | -0.9 ± 1.31 |
| **T1-T4** | -4.3 ± 0.85 | -0.8 ± 0.99* |
| **Patients** | 4 | 16 |
| **T4-T5** | -0.3 ± 0.56 | -0.9 ± 0.92 |
| **T1-T5** | -3.1 ± 2.73 | -3.0 ± 1.05 |

Statistical difference at T1-T4 ($P < 0.05$) between screw and wire fixation groups.

### 8.4.2. *Interincisal angle (Table 8.13)*

*Screw fixation (N= 18)*

A mean increase of 1.5 ± 1.39° was measured at surgery. There were no significant changes following surgery. The net change (T1-T4) of 1.4 ± 1.55° was not significant. The four long term patients had a slightly larger increase in interincisal angle at surgery but this changed minimally thereafter.

*Wire fixation (N = 22)*

The magnitude of the mean changes was small for all periods. The mean net change resulting from surgery was a non-significant increase of 1.6 ± 1.50°. Changes for the 16 long term patients showed similar mean values as the intermediate (T4) group. The overall change in interincisal angle was 2.6 ± 1.64°.

**Table 8.13: Changes in interincisal angle (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | 18 | 22 |
| **T1-T2** | 1.5 ± 1.39 | 0.4 ± 1.08 |
| **T2-T3** | 0.6 ± 1.30 | 0.4 ± 1.15 |
| **T3-T4** | -0.4 ± 1.43 | 0.5 ± 1.79 |
| **T2-T4** | 0.1 ± 0.97 | 1.2 ± 1.94 |
| **T1-T4** | 1.4 ± 1.55 | 1.6 ± 1.50 |
| **Patients** | 4 | 16 |
| **T4-T5** | 0.1 ± 0.97 | -0.3 ± 0.99 |
| **T1-T5** | 5.0 ± 4.76 | 2.6 ± 1.64 |

No significant difference between groups.

### 8.4.3. *Lower incisal angle (Table 8.14)*

*Screw fixation (N = 18) and Wire fixation (N= 22)*

The mean lower incisal angle did not alter appreciably for any of the periods for the screw fixation group. The wire fixation patients had a mean reduction of -3.7 ± 1.00° at surgery. This was a statistically significant difference from the screw fixation group at the 0.5% level. The T1-T4 value was also statistically different at the 5% level.

**Table 8.14: Changes in lower incisal angle (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | 18 | **22** |
| **T1-T2** | 0.2 ± 0.58 | -3.7 ± 1.00** |
| **T2-T3** | -0.2 ± 0.93 | 1.0 ± 1.28 |
| **T3-T4** | 0.0 ± 0.81 | -1.5 ± 1.35 |
| **T2-T4** | -0.3 ± 1.16 | -1.3 ± 1.24 |
| **T1-T4** | -0.1 ± 1.23 | -5.0 ± 1.15* |
| **Patients** | 4 | **16** |
| **T4-T5** | -0.4 ± 0.96 | 0.9 ± 0.84 |
| **T1-T5** | -3.4 ± 3.49 | -4.6 ± 1.28 |

Significant differences between groups at T1-T2 ($P < 0.005$) and T1-T4 ($P < 0.05$).

### 8.4.4. *Overjet (Table 8.15)*

*Screw fixation (N= 18)*

The screw fixation group (N = 18) had an average reduction in overjet of -5.6 ± 0.54 mm at T2. Minimal changes in the mean values were measured postsurgically for intermediate and long term patients.

*Wire fixation*

The wire fixation group (N = 22) showed a mean reduction of -5.3 ± 0.52 mm at surgery and a subsequent increase of 1.2 ± 0.35 mm over the next 12 months. Both changes (T1-T2 and T3-T4) were statistically significant at the 0.5% level. No statistically significant difference was shown when the screw and wire fixation groups were compared by Student's *t*-test for unpaired values.

**Table 8.15: Changes in overjet (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| Patients | 18 | 22 |
| T1-T2 | -5.6 ± 0.54 | -5.3 ± 0.52 |
| T2-T3 | 0.0 ± 0.50 | -0.2 ± 0.27 |
| T3-T4 | 0.3 ± 0.34 | 1.2 ± 0.35 |
| T2-T4 | 0.4 ± 0.52 | 1.1 ± 0.30 |
| T1-T4 | -5.2 ± 0.58 | -4.2 ± 0.50 |
| Patients | 4 | 16 |
| T4-T5 | 0.1 ± 0.17 | 1.0 ± 0.37 |
| T1-T5 | -3.7 ± 0.75 | -3.5 ± 0.71 |

No significant differences between groups.

### 8.4.5. *Overbite (Table 8.16)*

*Screw fixation (N= 18)*

A mean reduction of -2.3 ± 0.77 mm was measured for the subset. A significant ($P < 0.05$) change was measured between T3 and T4 (1.0 ± 0.40 mm). The resultant change following surgery (T2-T4) was a mean increase of 1.6 ± 0.46 mm giving a net change (T1-T4) of -0.8 ± 0.47 mm. The four long term patients finished with a net reduction in overbite of -1.4 mm.

*Wire fixation (N = 22)*

A mean decrease in overbite of -3.8 ± 0.54 mm resulted from surgery. A highly significant increase in overbite between T3 and T4 occurred (1.5 ± 0.44 mm). The mean change resulting from surgery was a reduction in overbite of -1.6 ± 0.41 mm. The 16 long term patients showed similar mean values as the intermediate (T4) group. Minimal changes occurred between T4 and T5. The overall change in overbite was -1.3 ± 0.50 mm.

**Table 8.16: Changes in overbite (T1-T5) for bilateral sagittal split advancement (BSSA) with screw and wire fixation.**

| GROUP | SCREW FIXATION | WIRE FIXATION |
|---|---|---|
| **Patients** | **18** | **22** |
| **T1-T2** | -2.3 ± 0.77 | -3.8 ± 0.54 |
| **T2-T3** | 0.9 ± 0.30 | -0.2 ± 0.27 |
| **T3-T4** | 1.0 ± 0.40 | 1.5 ± 0.44 |
| **T2-T4** | 1.6 ± 0.46 | 2.3 ± 0.38 |
| **T1-T4** | -0.8 ± 0.47 | -1.6 ± 0.41 |
| **Patients** | **4** | **16** |
| **T4-T5** | -0.4 ± 0.47 | -0.1 ± 0.29 |
| **T1-T5** | -1.4 ± 0.42 | -1.3 ± 0.50 |

No significant differences between groups.

# CHAPTER 9

# RESULTS
# CORRELATIONS

The correlations between relapse and selected variables are tabulated in Tables 9.1 to 9.6. Table 9.1 correlates values for the total patient sample (N = 40). Tables 9.2 and 9.3 summarise the degrees of association for the screw fixation group (N = 18) and wire fixation group respectively (N = 22). Tables 9.4 sets out the correlation values for patients with less than 10% relapse at T4 (N = 6). Table 9.5 relates associations for patients who displayed between 10 and 25% relapse (N = 32). Table 9.6 correlates variables with relapse in excess of 25%.

## *9.1. AGE OF PATIENT AND RELAPSE AT B POINT*

### *9.1.1. All Subjects*

When all subjects were included, the correlation between age and postoperative movement at B point was low for both the intermediate (T4: $r = 0.025$) and long term (T5: $r = 0.106$).

### *9.1.2. Females*

No correlation was shown for females when age was compared against horizontal change at B point at T4 ($r = 0.02$; N= 29) or T5 ($r = 0.168$; N = 14). Similarly, there was no significant association between female age and relapse when expressed as a percentage of the initial advancement. No correlation could be shown for these parameters when females were grouped according to the method of fixation.

**TABLE 9.1: CORRELATION BETWEEN RELAPSE % AND MOVEMENT AT B POINT WITH OTHER VARIABLES.**

| ALL PATIENTS | RELAPSE % T2-T3 | RELAPSE % T2-T4 | RELAPSE % T2-T5 | B T1-T2 | B T2-T3 | B T2-T4 | B T2-T5 | AGE | GO ARC T1-T2 | GO ARC T2-T3 | PFH T1-T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RELAPSE % T2-T4 | 0.489 | 1 | | | | | | | | | |
| RELAPSE % T2-T5 | 0.231 | 0.852 | 1 | | | | | | | | |
| B T1-T2 | 0.287 | 0.040 | 0.061 | 1 | | | | | | | |
| B T2-T3 | 0.841 | 0.495 | 0.299 | 0.521 | 1 | | | | | | |
| B T2-T4 | 0.504 | 0.864 | 0.754 | 0.441 | 0.637 | 1 | | | | | |
| B T2-T5 | 0.400 | 0.861 | 0.929 | 0.131 | 0.495 | 0.895 | 1 | | | | |
| AGE | 0.247 | 0.062 | 0.091 | 0.314 | 0.078 | 0.072 | 0.081 | 1 | | | |
| GO ARC T1-T2 | 0.001 | 0.222 | 0.142 | 0.227 | 0.068 | 0.330 | 0.171 | 0.098 | 1 | | |
| GO ARC T2-T3 | 0.047 | 0.128 | 0.157 | 0.236 | 0.111 | 0.142 | 0.140 | 0.266 | 0.615 | 1 | |
| PFH T1-T2 | 0.072 | 0.287 | 0.185 | 0.067 | 0.042 | 0.336 | 0.192 | 0.067 | 0.938 | 0.534 | 1 |
| SNGoMe T1 | 0.013 | 0.221 | 0.191 | 0.362 | 0.123 | 0.330 | 0.100 | 0.437 | 0.069 | 0.092 | 0.099 |

**TABLE 9.2: CORRELATION BETWEEN RELAPSE % AND MOVEMENT AT B POINT WITH OTHER VARIABLES.**

| SCREW FIXATION | RELAPSE % T2-T3 | RELAPSE % T2-T4 | RELAPSE % T2-T5 | B T1-T2 | B T2-T3 | B T2-T4 | B T2-T5 | AGE | GO ARC T1-T2 | GO ARC T2-T3 | PFH T1-T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RELAPSE % T2-T4 | 0.425 | 1 | | | | | | | | | |
| RELAPSE % T2-T5 | 0.926 | 0.967 | 1 | | | | | | | | |
| B T1-T2 | 0.241 | 0.064 | 0.441 | 1 | | | | | | | |
| B T2-T3 | 0.768 | 0.363 | 0.660 | 0.536 | 1 | | | | | | |
| B T2-T4 | 0.470 | 0.844 | 0.933 | 0.401 | 0.593 | 1 | | | | | |
| B T2-T5 | 0.963 | 0.958 | 0.922 | 0.321 | 0.748 | 0.948 | 1 | | | | |
| AGE | 0.291 | 0.113 | 0.304 | 0.372 | 0.072 | 0.094 | 0.222 | 1 | | | |
| GO ARC T1-T2 | 0.104 | 0.227 | 0.406 | 0.102 | 0.076 | 0.350 | 0.347 | 0.098 | 1 | | |
| GO ARC T2-T3 | 0.027 | 0.243 | 0.573 | 0.108 | 0.068 | 0.235 | 0.068 | 0.081 | 0.463 | 1 | |
| PFH T1-T2 | 0.155 | 0.262 | 0.660 | 0.043 | 0.171 | 0.307 | 0.558 | 0.029 | 0.962 | 0.504 | 1 |
| SNGoMe T1 | 0.120 | 0.247 | 0.327 | 0.548 | 0.198 | 0.427 | 0.360 | 0.555 | 0.077 | 0.188 | 0.005 |

**TABLE 9.3: CORRELATION BETWEEN RELAPSE % AND MOVEMENT AT B POINT WITH OTHER VARIABLES.**

| **WIRE FIXATION** | RELAPSE % T2-T3 | RELAPSE % T2-T4 | RELAPSE % T2-T5 | B T1-T2 | B T2-T3 | B T2-T4 | B T2-T5 | AGE | GO ARC T1-T2 | GO ARC T2-T3 | PFH T1-T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RELAPSE % T2-T4 | 0.576 | 1 | | | | | | | | | |
| RELAPSE % T2-T5 | 0.115 | 0.804 | 1 | | | | | | | | |
| B T1-T2 | 0.358 | 0.133 | 0.078 | 1 | | | | | | | |
| B T2-T3 | 0.929 | 0.603 | 0.214 | 0.558 | 1 | | | | | | |
| B T2-T4 | 0.567 | 0.870 | 0.677 | 0.505 | 0.691 | 1 | | | | | |
| B T2-T5 | 0.333 | 0.814 | 0.905 | 0.186 | 0.457 | 0.869 | 1 | | | | |
| AGE | 0.197 | 0.041 | 0.038 | 0.290 | 0.101 | 0.053 | 0.174 | 1 | | | |
| GO ARC T1-T2 | 0.102 | 0.244 | 0.081 | 0.300 | 0.200 | 0.335 | 0.157 | 0.256 | 1 | | |
| GO ARC T2-T3 | 0.083 | 0.136 | 0.069 | 0.283 | 0.200 | 0.171 | 0.073 | 0.222 | 0.627 | 1 | |
| PFH T1-T2 | 0.006 | 0.305 | 0.083 | 0.137 | 0.069 | 0.354 | 0.128 | 0.144 | 0.923 | 0.547 | 1 |
| SNGoMe T1 | 0.141 | 0.147 | 0.178 | 0.276 | 0.018 | 0.235 | 0.061 | 0.314 | 0.211 | 0.023 | 0.218 |

**TABLE 9.4: CORRELATION BETWEEN RELAPSE % AND MOVEMENT AT B POINT WITH OTHER VARIABLES.**

| **RELAPSE < 10% (N = 8)** | RELAPSE % T2-T3 | RELAPSE % T2-T4 | RELAPSE % T2-T5 | B T1-T2 | B T2-T3 | B T2-T4 | B T2-T5 | AGE | GO ARC T1-T2 | GO ARC T2-T3 | PFH T1-T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RELAPSE % T2-T4 | 0.531 | 1 | | | | | | | | | |
| RELAPSE % T2-T5 | 0.653 | 0.320 | 1 | | | | | | | | |
| B T1-T2 | 0.927 | 0.278 | 0.016 | 1 | | | | | | | |
| B T2-T3 | 0.953 | 0.616 | 0.440 | 0.781 | 1 | | | | | | |
| B T2-T4 | 0.465 | 0.994 | 0.368 | 0.174 | 0.564 | 1 | | | | | |
| B T2-T5 | 0.205 | 0.124 | 0.888 | 0.166 | 0.049 | 0.083 | 1 | | | | |
| AGE | 0.727 | 0.105 | 0.033 | 0.626 | 0.932 | 0.159 | 0.421 | 1 | | | |
| GO ARC T1-T2 | 0.054 | 0.626 | 0.749 | 0.166 | 0.148 | 0.646 | 0.574 | 0.051 | 1 | | |
| GO ARC T2-T3 | 0.115 | 0.808 | 0.907 | 0.226 | 0.102 | 0.825 | 0.997 | 0.040 | 0.702 | 1 | |
| PFH T1-T2 | 0.597 | 0.332 | 0.550 | 0.260 | 0.520 | 0.397 | 0.429 | 0.138 | 0.622 | 0.701 | 1 |
| SNGoMe T1 | 0.466 | 0.262 | 0.594 | 0.157 | 0.243 | 0.285 | 0.241 | 0.271 | 0.852 | 0.363 | 0.601 |

**TABLE 9.5: CORRELATION BETWEEN RELAPSE % AND MOVEMENT AT B POINT WITH OTHER VARIABLES.**

| **RELAPSE 10-25% (N = 10)** | RELAPSE % T2-T3 | RELAPSE % T2-T4 | RELAPSE % T2-T5 | B T1-T2 | B T2-T3 | B T2-T4 | B T2-T5 | AGE | GO ARC T1-T2 | GO ARC T2-T3 | PFH T1-T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RELAPSE % T2-T4 | 0.268 | 1 | | | | | | | | | |
| RELAPSE % T2-T5 | 0.498 | 0.965 | 1 | | | | | | | | |
| B T1-T2 | 0.386 | 0.288 | 0.917 | 1 | | | | | | | |
| B T2-T3 | 0.921 | 0.024 | 0.629 | 0.661 | 1 | | | | | | |
| B T2-T4 | 0.233 | 0.649 | 0.949 | 0.839 | 0.584 | 1 | | | | | |
| B T2-T5 | 0.544 | 0.978 | 0.999 | 0.894 | 0.670 | 0.931 | 1 | | | | |
| AGE | 0.334 | 0.217 | 0.035 | 0.129 | 0.196 | 0.079 | 0.089 | 1 | | | |
| GO ARC T1-T2 | 0.244 | 0.140 | 0.533 | 0.436 | 0.331 | 0.525 | 0.486 | 0.442 | 1 | | |
| GO ARC T2-T3 | 0.710 | 0.035 | 0.725 | 0.581 | 0.762 | 0.594 | 0.686 | 0.519 | 0.830 | 1 | |
| PFH T1-T2 | 0.163 | 0.146 | 0.369 | 0.285 | 0.241 | 0.424 | 0.318 | 0.296 | 0.928 | 0.692 | 1 |
| SNGoMe T1 | 0.109 | 0.389 | 0.997 | 0.826 | 0.393 | 0.770 | 1.000 | 0.552 | 0.126 | 0.193 | 0.096 |

**TABLE 9.6: CORRELATION BETWEEN RELAPSE % AND MOVEMENT AT B POINT WITH OTHER VARIABLES.**

| **RELAPSE > 25% (N = 22)** | RELAPSE % T2-T3 | RELAPSE % T2-T4 | RELAPSE % T2-T5 | B T1-T2 | B T2-T3 | B T2-T4 | B T2-T5 | AGE | GO ARC T1-T2 | GO ARC T2-T3 | PFH T1-T2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RELAPSE % T2-T4 | 0.419 | 1 | | | | | | | | | |
| RELAPSE % T2-T5 | 0.007 | 0.554 | 1 | | | | | | | | |
| B T1-T2 | 0.069 | 0.278 | 0.268 | 1 | | | | | | | |
| B T2-T3 | 0.584 | 0.108 | 0.080 | 0.483 | 1 | | | | | | |
| B T2-T4 | 0.404 | 0.507 | 0.298 | 0.662 | 0.526 | 1 | | | | | |
| B T2-T5 | 0.307 | 0.789 | 0.540 | 0.111 | 0.241 | 0.862 | 1 | | | | |
| AGE | 0.093 | 0.156 | 0.211 | 0.385 | 0.227 | 0.430 | 0.157 | 1 | | | |
| GO ARC T1-T2 | 0.241 | 0.202 | 0.338 | 0.183 | 0.095 | 0.388 | 0.333 | 0.020 | 1 | | |
| GO ARC T2-T3 | 0.016 | 0.188 | 0.203 | 0.012 | 0.070 | 0.156 | 0.375 | 0.150 | 0.541 | 1 | |
| PFH T1-T2 | 0.298 | 0.222 | 0.339 | 0.059 | 0.215 | 0.301 | 0.296 | 0.054 | 0.969 | 0.550 | 1 |
| SNGoMe T1 | 0.108 | 0.143 | 0.448 | 0.250 | 0.091 | 0.320 | 0.007 | 0.501 | 0.257 | 0.382 | 0.297 |

### 9.1.3. *Males*

A moderate correlation between age and forward movement at B point was shown to exist for males at T4 ($r$ = 0.404; N = 11; Figure 9.1). However, a strong correlation was noted between age and change at B point at T5 ($r$ = 0.935; $P$ < 0.02; N = 5; Figure 9.2). Thus as age increased, B point moved backwards.

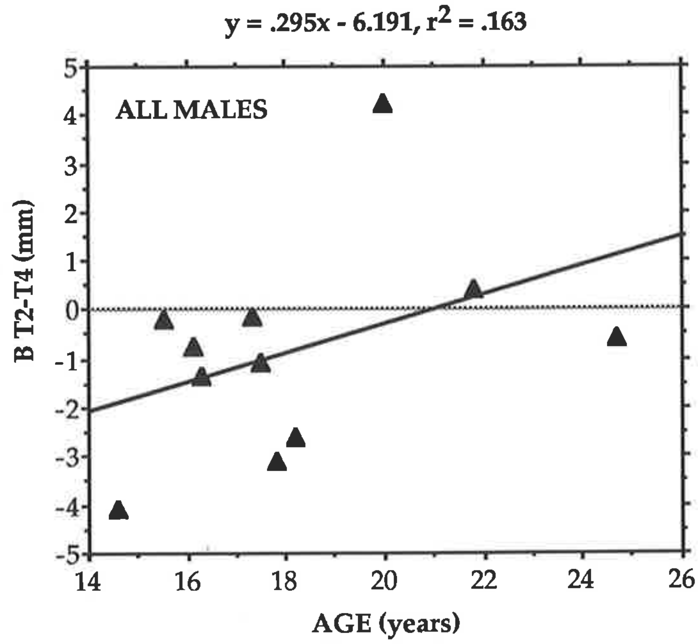



**Figure 9.1: Correlation between age and movement at B point in males 12 months after surgery.**

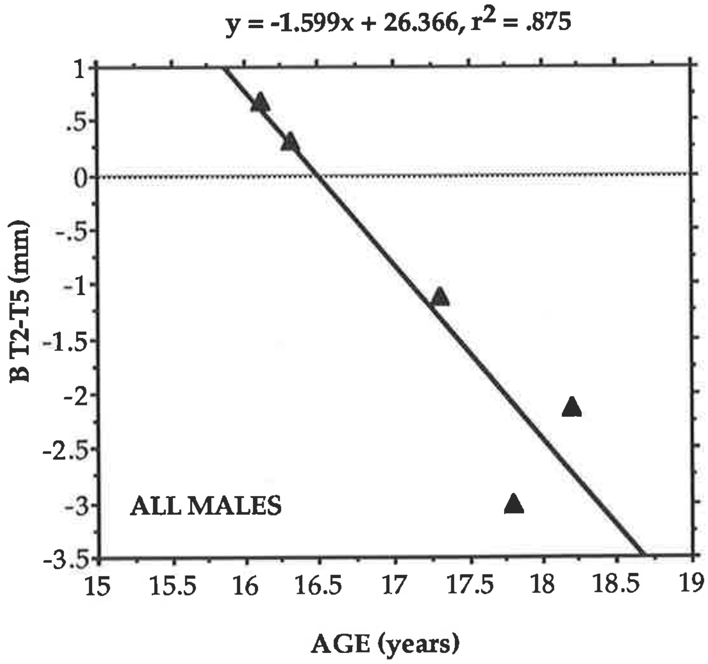



**Figure 9.2: Correlation between age and movement at B point in males 24 months after surgery.**

A weak negative correlation was shown between age and relapse when expressed as a percentage of the initial advancement at T4 ($r$ = -0.313; $r^2$ = 0.098; Figure 9.3). A strong correlation was again expressed for T5 ($r$ = 0.890; $r^2$ = 0.791; Figure 9.4). Thus as age increased, relapse % increased.

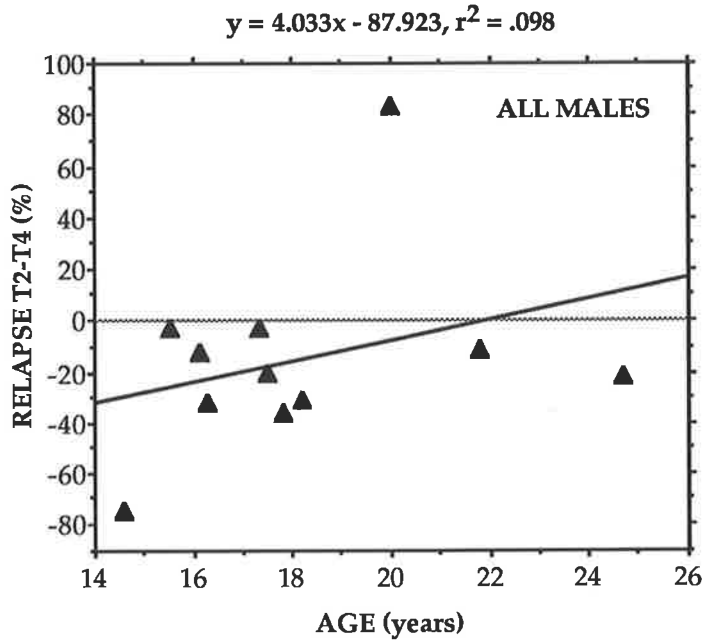



**Figure 9.3: Correlation between age and % relapse at B point in males 12 months after surgery.**

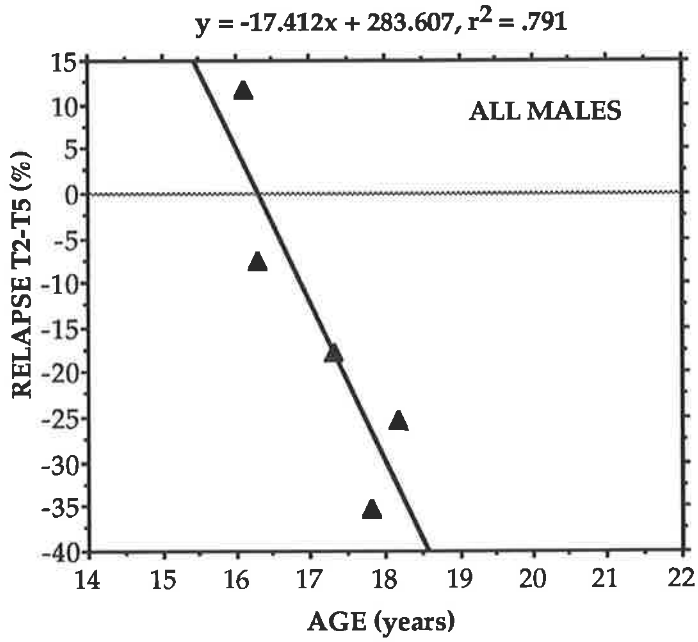



**Figure 9.4: Correlation between age and % relapse at B point in males 24 months after surgery.**

#### 9.1.3.1. *Wire fixation*

For males treated with wire fixation, a weak correlation ($r$ = 0.241) was shown at T5 for relative change at B point. Moderate correlations were shown when age was compared to the change as a percentage of initial advancement at T4 ($r$ = 0.553; $r^2$ = 0.306) and T5 ($r$ = 0.577; $r^2$ = 0.333).

#### 9.1.3.2. *Screw fixation*

For the screw fixation group of males (N = 4), a strong correlation ($r$ = 0.624; $r^2$ = 0.39) was found between age and positive movement of B point at T4. There was a moderate association ($r$ = 0.498; $r^2$ = 0.248) between age and percentage change at B point. Since only two cases existed at T5 a correlation coefficient was not calculated.

*9.2. MAGNITUDE OF ADVANCEMENT*

A moderate association was demonstrated between the magnitude of the surgical advancement and negative movement at B point after 12 months when all subjects were included ($r = 0.446$; $P < 0.005$; Figure 9.5). Thus, the greater the initial surgical advancement, the greater the likelihood of postsurgical relapse within one year.

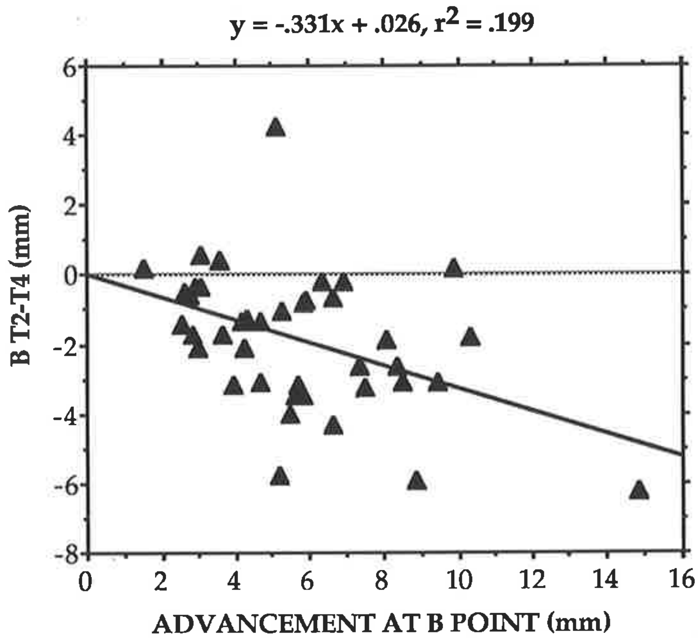



**Figure 9.5: Correlation between advancement at B point and backward movement at B point after 12 months (N = 40).**

The screw fixation group (N = 18) displayed a moderate correlation ($r = 0.401$; $r^2 = 0.161$; Figure 9.6) between advancement and 12 month relapse at B point. The correlation amongst females (N = 14) was 0.436 and 0.324 for males (N =4). This difference was not statistically significant. For the 4 long term cases, there was a weak negative correlation ($r = 0.321$; $r^2 = 0.103$). However, only weak correlation values were shown between advancement at B point and the percentage change at T4. Females had an $r$ value of 0.317 and males, 0.006.

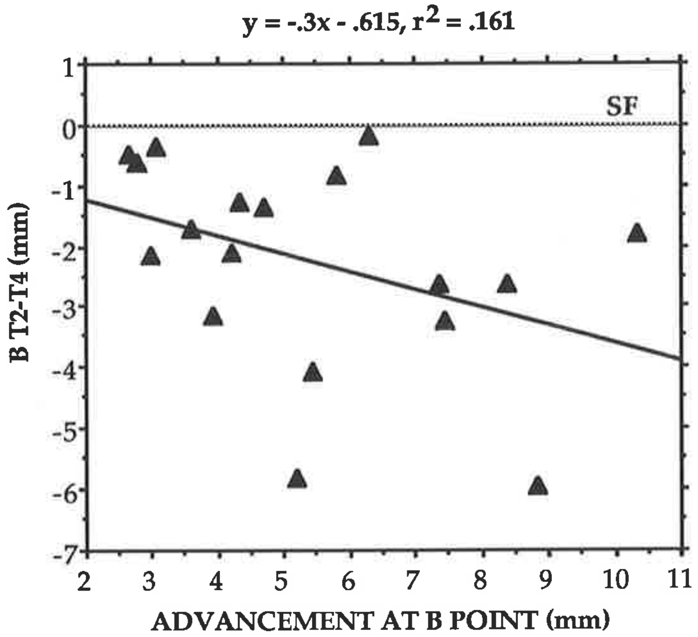



**Figure 9.6: Correlation between advancement at B point and relapse after 12 months for the screw fixation group (N = 18).**

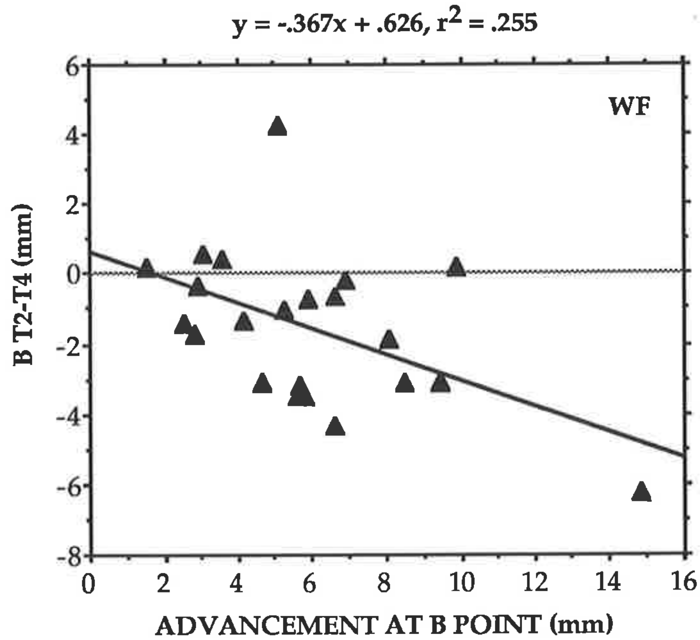



**Figure 9.7: Correlation between advancement at B point and relapse after 12 months for the wire fixation group (N = 22).**

The wire fixation group (Figure 9.7) showed a stronger relationship between the magnitude of advancement and relapse at T4 ($r$ = 0.505; $r^2$ = 0.255) but a low correlation at T5 ($r$ = 0.186; $r^2$ = 0.034). When compared by sex, the correlation values for females at T4 (N = 15) and T5 (N = 12) were 0.587 and 0.056 respectively. Correlation values were low (0.079 and 0.177) when compared to the percentage change at B point.

For the male patients, correlations varied from 0.448 at T4 (N = 7) to 0.916 at T5 (N = 4). Comparison with percentage change at B point gave correlations of 0.307 and 0.926 for each time period.

*9.3. GONIAL ARC RADIUS*

### *9.3.1. All Patients*

Fourteen patients had less than 0.4 mm increase in gonial arc radius at surgery. There was a moderate correlation between gonial arc radius (T1-T2) and relapse ($r$ = 0.437). Thus relapse occurred even if gonial arc radius shortened at the time of surgery (Figure 9.8).

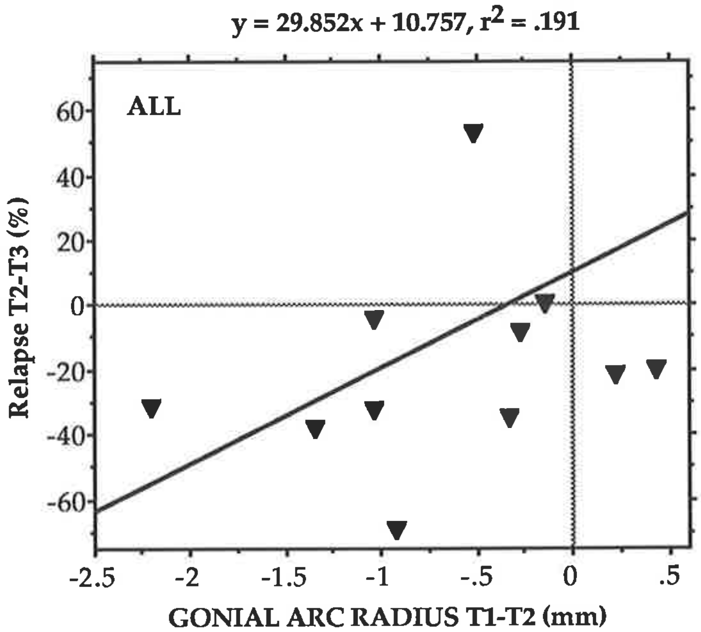



**Figure 9.8: Correlation between change in gonial arc radius (< 0.4 mm) and % relapse at B point during the first six weeks for all patients (N = 14).**

Twenty-six patients had increases in gonial arc (> 0.4 mm) but the correlation with early relapse % was very low ($r$ = 0.068; Figure 9.9). Although there was only a weak correlation with intermediate relapse ($r$ = 0.383), a moderate association was observed between increased gonial arc and movement at B point over 12 months (Figure 9.10).

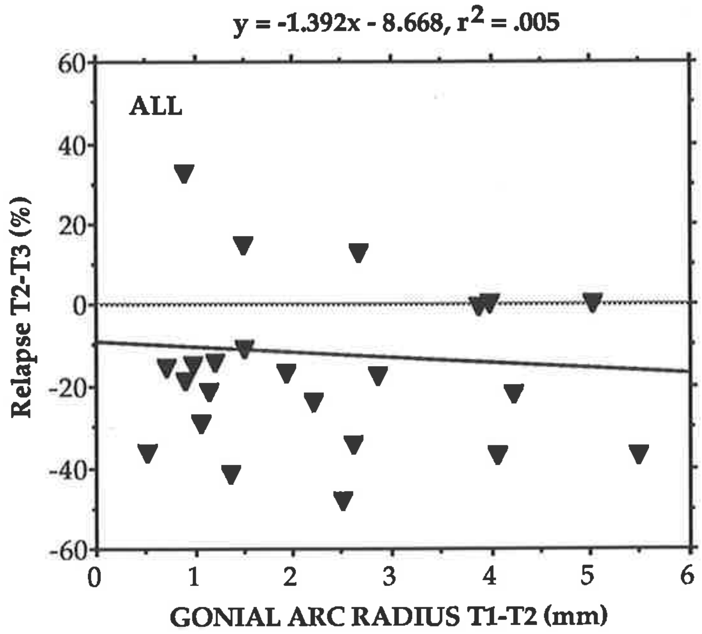



**Figure 9.9:** Correlation between change in gonial arc radius (> 0.4 mm) and % relapse at B point during the first six weeks for all patients (N = 26).

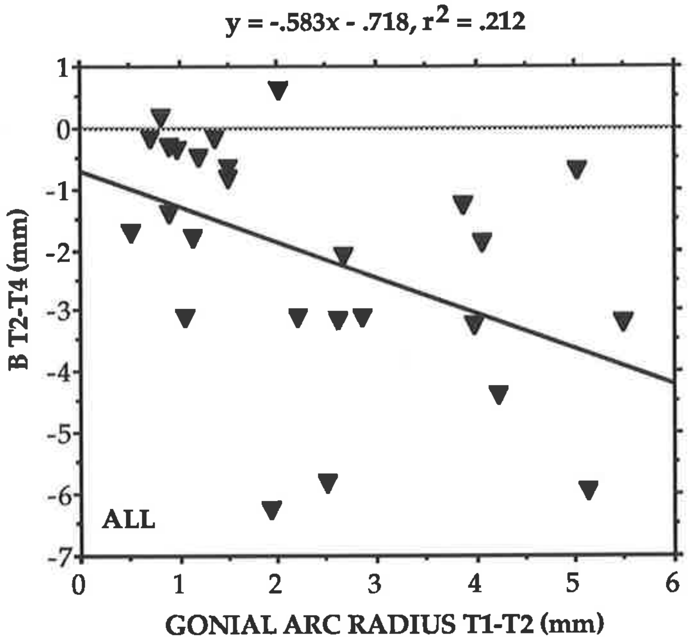



**Figure 9.10:** Correlation between change in gonial arc radius (> 0.4 mm) and movement at B point during the first 12 months for all patients (N = 26).

*9.3.2. Screw fixation*

No correlation was found between surgically increased gonial arc radius and movement at B point for any interval. A strong association ($r$ = 0.372) between surgically increased gonial arc (> 0.4 mm) and subsequent early (T3) relapse per cent was shown in the screw fixation group (N = 12). A strong association was shown for intermediate movement at B point (T4: $r$ = 0.689; $P$ < 0.05; Figure 9.11) and intermediate % relapse ($r$ = 0.429).

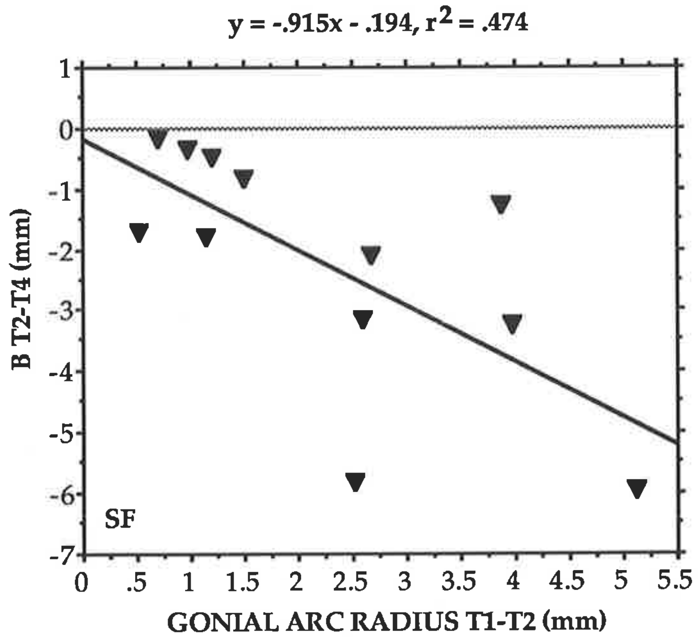



**Figure 9.11: Correlation between change in gonial arc radius (> 0.4 mm) and movement at B point during the first 12 months for the screw fixation group (N = 12).**

There were 6 cases in which gonial arc radius did not exceed 0.4 mm. No correlation was found between minimally altered gonial arc radius and early or intermediate relapse per cent ($r$ = 0.117).

### 9.3.3. *Wire fixation*

Low correlations were noted for surgical (T2) and early (T3) changes in gonial arc radius and subsequent relapse at B point for all subjects (N = 22). Fourteen patients had surgically increased gonial arc radius but showed only a weak association with early relapse (*r* = 0.251; Figure 9.12). Low correlations were shown with intermediate (T4) relapse (*r* = 0.350) and T4 movement at B point (*r* = -0.297).

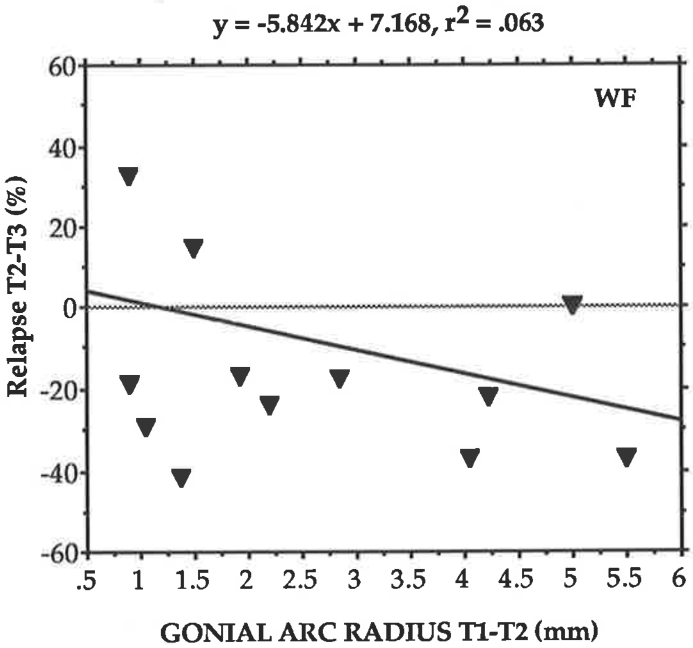



**Figure 9.12: Correlation between change in gonial arc radius (> 0.4 mm) and % relapse at B point during the first six weeks for the wire fixation group (N = 14).**

The eight patients who had less than 0.4 mm change in gonial arc at surgery showed low correlations with per cent relapse at T3 (*r* = 0.116) and relapse at T4 (*r* = 0.056).

### *9.4. POSTERIOR FACIAL HEIGHT*

There was a low negative correlation between surgically altered posterior facial height and T4 movement at B point ($r$ = -0.307). Low correlations with per cent relapse at T4 ($r$ = 0.287; N = 40) and T5 ( $r$ = 0.185; N = 20) were expressed.

#### *9.4.1. Screw fixation*

The 18 patients showed a low negative correlation between posterior facial height and movement at B point ($r$ = -0.307). No correlation with percentage relapse at T4 was shown but a strong correlation was displayed for the 4 long term cases ($r$ = 0.66). Males (N = 4) showed a moderate negative correlation ($r$ = -0.343) between posterior facial height and relapse.

The 14 females showed a moderate negative correlation between altered posterior facial height and movement at B point ($r$ = -0.481). The correlation between posterior facial height and percentage relapse at T4 was low (Figure 9.13).

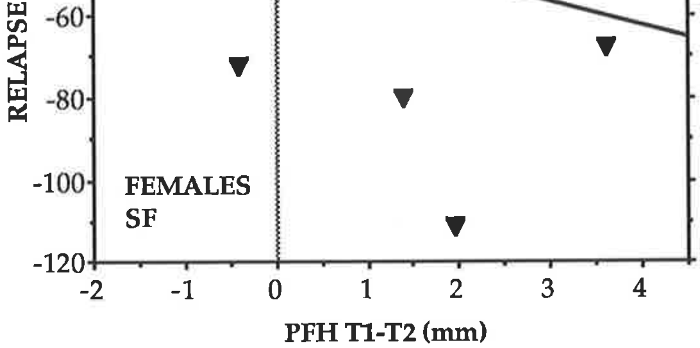



**Figure 9.13: Correlation between altered posterior facial height and percentage relapse at T4 for females in the screw fixation group (N = 14).**

Eight patients (3 males; 5 females) did not increase posterior facial height at surgery and showed a low correlation with 12 month relapse. Eleven patients (1 male; 10 females) had increased posterior facial height at surgery but showed a low negative correlation with 12 month relapse ($r$ = -0.203).

### 9.4.2. *Wire fixation*

Twenty-two patients in the wire fixation group showed a low correlation between posterior facial height and relapse at T4 ($r$ = 0.305). The correlation with movement at B point 12 months later was slightly higher ($r$ = 0.354). Seven males showed a low correlation with 12 month relapse ($r$ = 0.244) and 4 males, a low value at T5 ($r$ = 0.08). Fifteen females at T4 were not correlated with relapse at T4 ($r$ =0.137). Twelve females were followed to T5 and did not demonstrate a correlation with relapse ($r$ = -0.012).

The correlation with minimally altered posterior facial height and 12 month relapse was very low ($r$ = 0.072; N = 11). Increased posterior facial height (PFH > 0 mm) occurred for 11 patients and showed a low correlation with relapse ($r$ = 0.332).

## 9.5. PREOPERATIVE MANDIBULAR PLANE ANGLE

### 9.5.1. *All patients*

A weak association was demonstrated between the preoperative mandibular plane angle and early relapse % ($r$ = 0.013; Figure 9.1). Weak associations were also observed for intermediate relapse ($r$ = 0.208; Figure 9.15) and long term relapse ($r$ = 0.1).

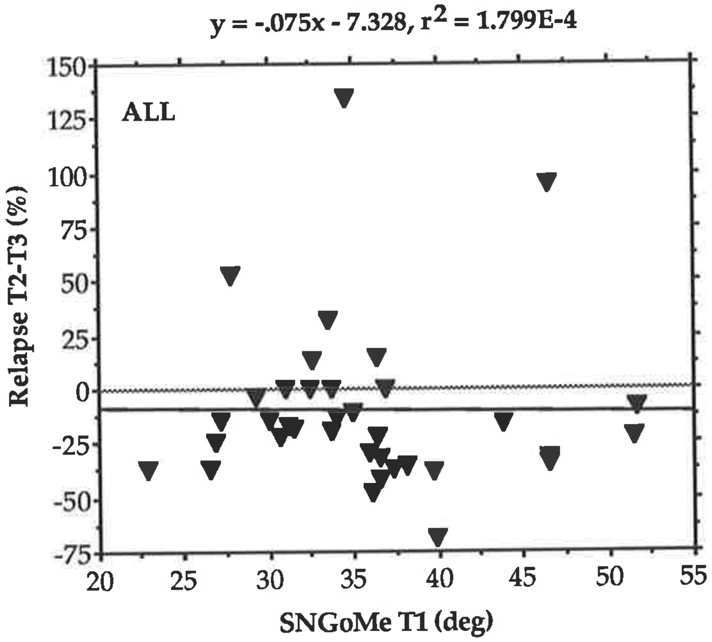



**Figure 9.14: Correlation between preoperative mandibular plane angle and subsequent relapse after 6 weeks (N = 40).**

### 9.5.2. *Screw fixation*

The screw fixation group (N = 18) displayed a weak correlation ($r$ = 0.247; Figure 9.16) between the preoperative mandibular plane angle and intermediate relapse %.

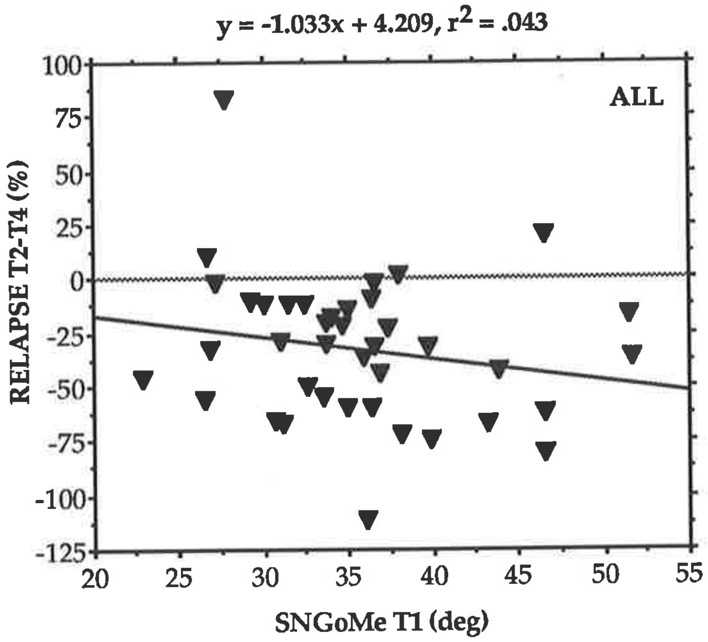



Figure 9.15: Correlation between preoperative mandibular plane angle and subsequent relapse after 12 months (N = 40).

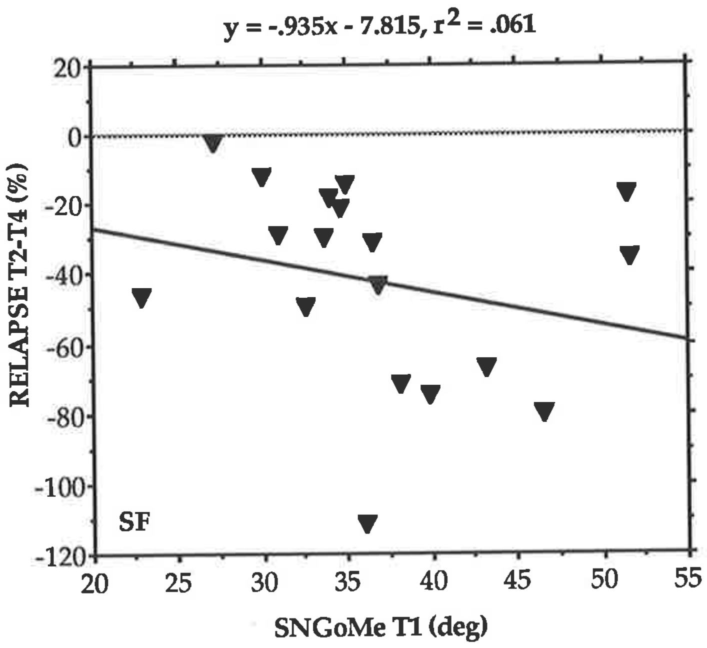



Figure 9.16: Correlation between preoperative mandibular plane angle and subsequent relapse after 12 months for the screw fixation group (N = 18).

### 9.5.3. *Wire fixation*

The wire fixation group (Figure 9.17) showed an even weaker relationship between the preoperative mandibular plane angle and intermediate relapse %$r$ = 0.122).

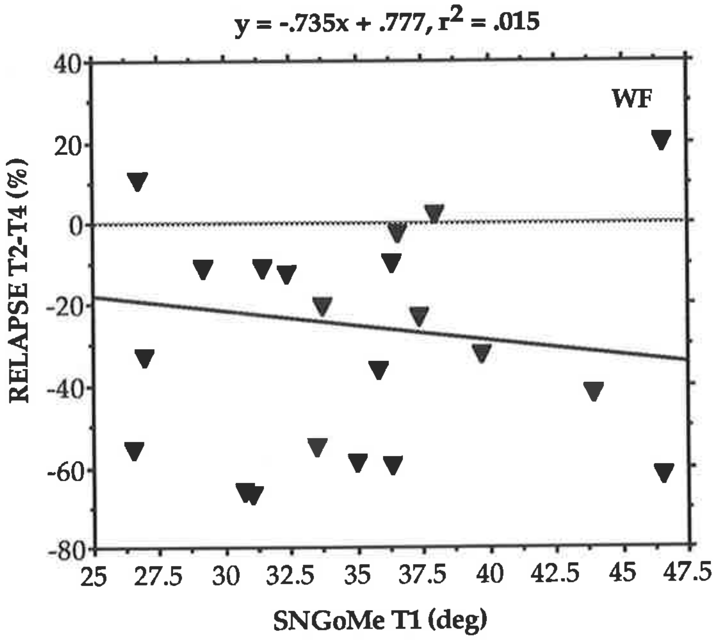



**Figure 9.17: Correlation between preoperative mandibular plane angle and subsequent relapse after 12 months for the wire fixation group (N = 22).**

### 9.6. HIGH VERSUS LOW RELAPSE

Tables 9.4 to 9.6 summarise the degrees of association between relapse % and selected variables. The total sample was separated into 3 groups: less than 10% relapse (N =8); between 10 to 25% relapse (N = 10); and greater than 25% relapse (N = 22).

There were relatively few cases which displayed low percentage relapse. These patients showed high correlations ($r$ = 0.626; $P$ < 0.05) with surgical change in gonial arc radius (Figure 9.18). A high correlation value showing subsequent condylar return was not statistically significant. The remaining correlations were weak or were not statistically significant.

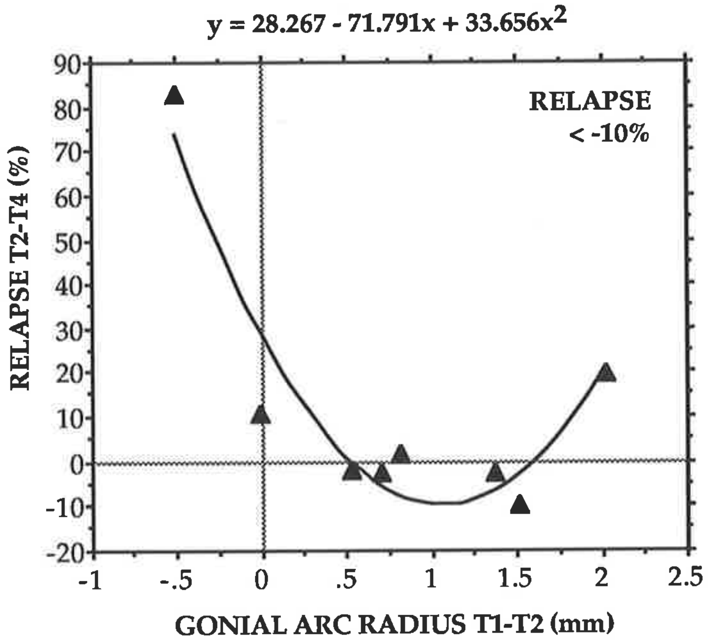



**Figure 9.18: Correlation between altered gonial arc radius and subsequent relapse after 12 months for patients with less than 10% relapse (N = 8).**

The patients with relapse between 10 and 25% showed a strong association ($r$ = 0.826; $P$ < 0.005) between preoperative mandibular plane angle and mandibular advancement (Figure 9.19). In the postoperative period T2-T4, a strong correlation ($r$ = 0.770; $P$ < 0.005) with relapse was shown (Figure 9.20).

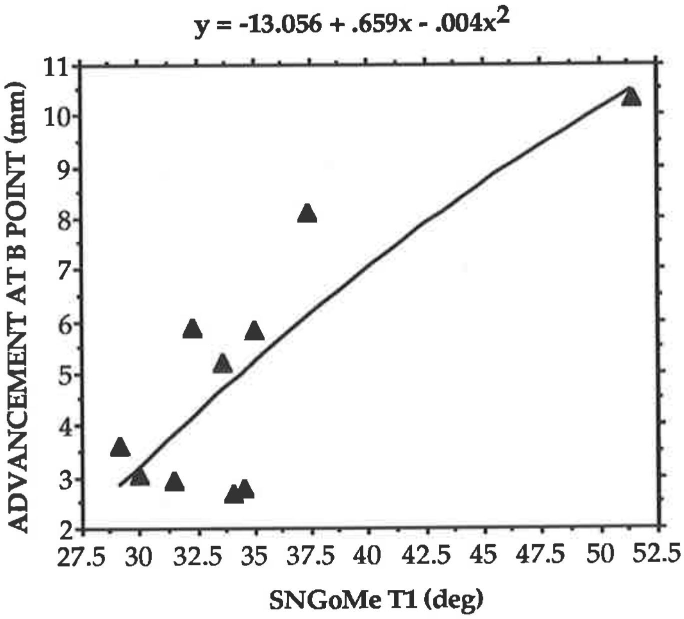



**Figure 9.19: Correlation between preoperative mandibular plane angle and surgical advancement for patients who displayed between 10 and 25% relapse at T4 (N = 10).**

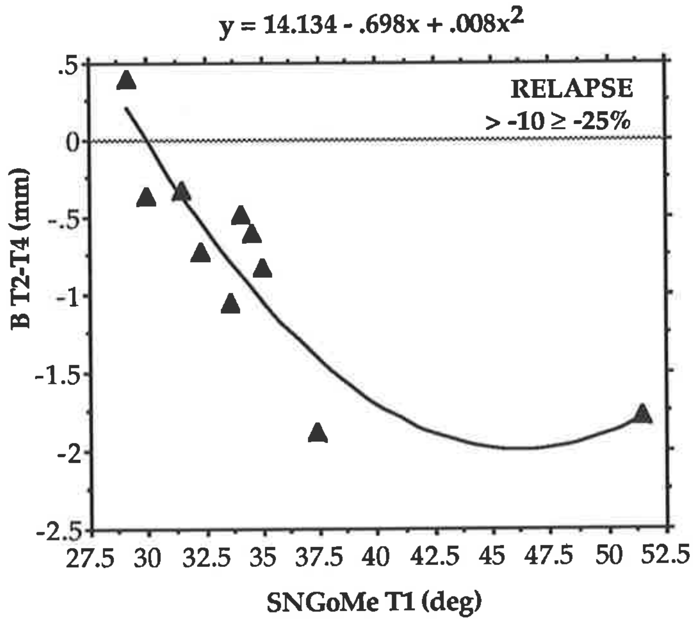



**Figure 9.20: Correlation between preoperative mandibular plane angle and postoperative change at B point for patients who displayed between 10 and 25% relapse at T4 (N = 10).**

The high relapse group did not show any consistent patterns of association and none of the correlations were statistically significant. Weak correlations between percentage relapse and gonial arc radius ($r$ = 0.202), advancement at B point ($r$ = 0.278) and preoperative mandibular plane angle ($r$ = 0.143) were expressed. No correlation with gonial angle was shown in the high relapse group.

# CHAPTER 10

# RESULTS
# ERRORS OF THE METHOD

## *10.1. ERRORS OF THE METHOD*

Tables 10.1 and 10.2 summarise the magnitude of errors in the horizontal and vertical axes for ten sets of double determinations. With the exception of measurement error, the methodology incorporated all errors into the reported values. None of the mean differences exceeded 0.6 mm in either the horizontal (x) or vertical (y) axis although the individual values for some points varied considerably. The standard errors of the mean differences varied from 0.07 to 0.69 and 0.13 to 0.54 in the x and y planes respectively.

The most variable point by gross error in both the horizontal and vertical plane was lower incisal apex (AI x, y). Discrepancies in the location of this point ranged from -3.20 to 3.33 mm in the horizontal plane and -2.52 to 2.35 mm in the vertical plane. The most reliable point in the horizontal plane was nasion (N x) with an error determination of 0.17 mm. Lower molar crown (MI y) was the most reliable point in the vertical plane with an error of 0.29 mm. For the remaining points, the standard deviation of a single determination did not exceed 1 mm except for the point AI (lower incisal apex). Review of the percentage of error variance showed that errors contributed between 0.03% (S x) to 1.88% (AI y) of the observed values.

The two-tail Student's t-test for paired values showed that two values (ANS x and S y) were significant at the 5% level even though the differences were numerically small in relation to the means of the variables. Figure 10.1 illustrates the distribution of differences for ANS x and S y. The graphical representation shows that there was a positive tendency for differences in ANS x. Smaller variations were found for S y but when present, there was a slight negative trend.

**Table 10.1. Error for 20 hard tissue points (horizontal axis) by double determination**

| Variable | M diff | E (M diff) | Min. | Max. | S (error) | Rank | % E var. |
|---|---|---|---|---|---|---|---|
| S x | 0.01 | 0.08 | -0.23 | 0.53 | 0.17 | 2 | 0.03 |
| N x | 0.02 | 0.07 | -0.35 | 0.51 | 0.15 | 1 | 0.06 |
| Po x | -0.59 | 0.31 | -2.52 | 0.73 | 0.79 | 18 | 0.46 |
| Or x | 0.03 | 0.14 | -0.66 | 0.89 | 0.30 | 7 | 0.18 |
| HA x | -0.40 | 0.30 | -2.75 | 0.53 | 0.70 | 16 | 0.56 |
| Co x | -0.58 | 0.29 | -2.80 | 0.28 | 0.73 | 17 | 1.28 |
| Ar x | -0.19 | 0.14 | -1.35 | 0.28 | 0.33 | 10 | 0.10 |
| Go x | -0.31 | 0.17 | -0.90 | 0.54 | 0.42 | 12 | 0.37 |
| Me x | -0.20 | 0.20 | -1.60 | 0.68 | 0.45 | 13 | 0.24 |
| Pg x | -0.24 | 0.16 | -1.02 | 0.49 | 0.37 | 11 | 0.35 |
| B x | -0.09 | 0.14 | -0.96 | 0.63 | 0.30 | 7 | 0.11 |
| A x | -0.12 | 0.12 | -0.49 | 0.47 | 0.28 | 4 | 0.24 |
| ANS x | 0.82 | 0.33* | -0.49 | 3.04 | 0.91 | 19 | 1.04 |
| PNS x | -0.02 | 0.29 | -1.15 | 1.56 | 0.62 | 15 | 0.85 |
| IS x | -0.09 | 0.15 | -0.80 | 0.67 | 0.32 | 9 | 0.15 |
| AS x | -0.07 | 0.14 | -0.65 | 0.60 | 0.30 | 7 | 0.11 |
| II x | -0.14 | 0.12 | -0.74 | 0.36 | 0.28 | 4 | 0.07 |
| AI x | -0.61 | 0.69 | -3.20 | 3.33 | 1.53 | 20 | 1.89 |
| MS x | -0.48 | 0.22 | -1.72 | 0.50 | 0.57 | 14 | 0.26 |
| MI x | -0.09 | 0.11 | -0.60 | 0.44 | 0.24 | 3 | 0.05 |

DF = 9
* = $P \leq 0.05$

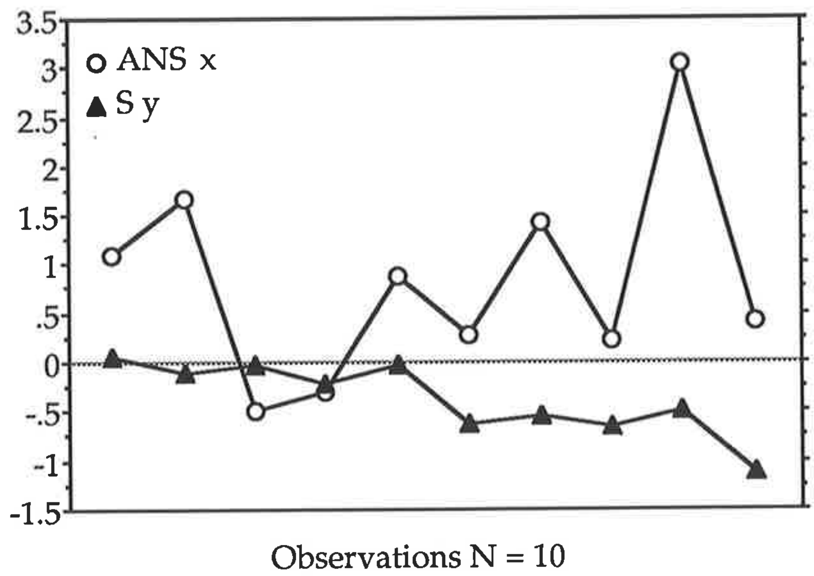



**Figure 10.1. Distribution of differences for ANS x and S y for 10 sets of double determinations.**

Rank order based on the Dahlberg statistic, S (error), showed that sella, nasion, lower molar crown, A point and lower incisal edge were the most reliable in the horizontal (x) axis. The least reliable points were lower incisal apex, anterior nasal spine, porion, condylion and hinge axis. Lower molar crown, articulare, condylion, lower incisal edge and sella ranked the highest in the vertical (y) plane. The least reliable points in this plane were lower incisal apex, porion, upper incisal apex and upper molar crown.

**Table 10.2. Error for 20 hard tissue points (vertical axis) by double determination**

| Variable | M diff | E (M diff) | Min. | Max. | S (error) | Rank | % E var. |
|---|---|---|---|---|---|---|---|
| S y | -0.37 | 0.12* | -1.11 | 0.07 | 0.36 | 5 | 0.12 |
| N y | -0.34 | 0.19 | -1.33 | 0.42 | 0.46 | 8 | 0.20 |
| Po y | 0.59 | 0.40 | -1.54 | 2.35 | 0.94 | 19 | 0.72 |
| Or y | -0.30 | 0.25 | -1.27 | 0.55 | 0.58 | 12 | 0.40 |
| HA y | -0.12 | 0.25 | -1.52 | 1.01 | 0.54 | 11 | 0.19 |
| Co y | -0.21 | 0.15 | -1.05 | 0.34 | 0.34 | 3 | 0.14 |
| Ar y | 0.07 | 0.15 | -0.69 | 0.80 | 0.33 | 2 | 0.14 |
| Go y | 0.28 | 0.20 | -0.80 | 1.22 | 0.46 | 8 | 0.28 |
| Me y | -0.20 | 0.16 | -0.88 | 0.60 | 0.37 | 6 | 0.10 |
| Pg y | -0.28 | 0.27 | -1.98 | 0.93 | 0.61 | 14 | 0.52 |
| B y | -0.16 | 0.28 | -1.53 | 1.46 | 0.61 | 14 | 0.33 |
| A y | 0.28 | 0.27 | -0.85 | 1.92 | 0.62 | 15 | 0.47 |
| ANS y | 0.18 | 0.31 | -1.04 | 1.92 | 0.68 | 17 | 0.41 |
| PNS y | -0.09 | 0.22 | -1.44 | 0.82 | 0.48 | 10 | 0.25 |
| IS y | -0.01 | 0.18 | -1.02 | 0.71 | 0.38 | 7 | 0.13 |
| AS y | 0.06 | 0.33 | -0.88 | 2.67 | 0.71 | 18 | 0.60 |
| II y | -0.20 | 0.15 | -0.99 | 0.83 | 0.35 | 4 | 0.07 |
| AI y | -0.24 | 0.54 | -2.52 | 2.35 | 1.16 | 20 | 1.88 |
| MS y | -0.23 | 0.31 | -1.12 | 1.78 | 0.67 | 16 | 0.29 |
| MI y | -0.14 | 0.13 | -0.93 | 0.65 | 0.29 | 1 | 0.10 |

DF = 9
* = $P \leq 0.05$

Scattergrams for each hard tissue point are illustrated as Figures 10.2 to 10.11. Each point showed errors in the horizontal (x) and vertical (y) plane.

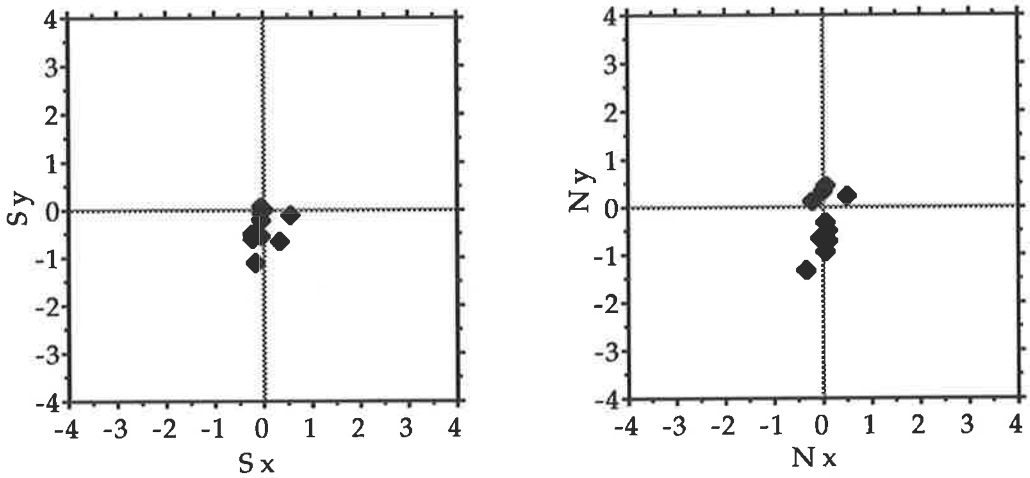



**Figure 10.2: Differences between digitised double determinations for sella (S) and nasion (N).**

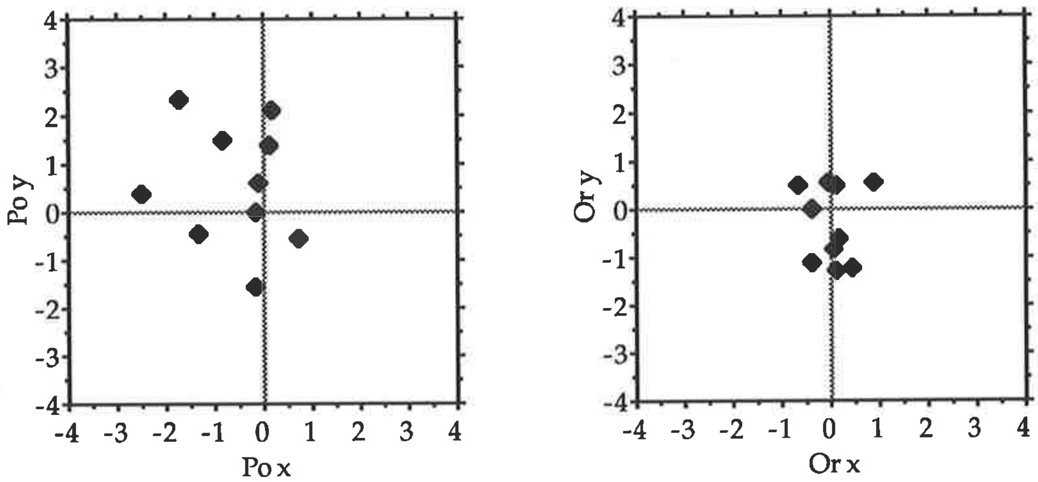



**Figure 10.3: Differences between digitised double determinations for porion (Po) and orbitale (Or).**

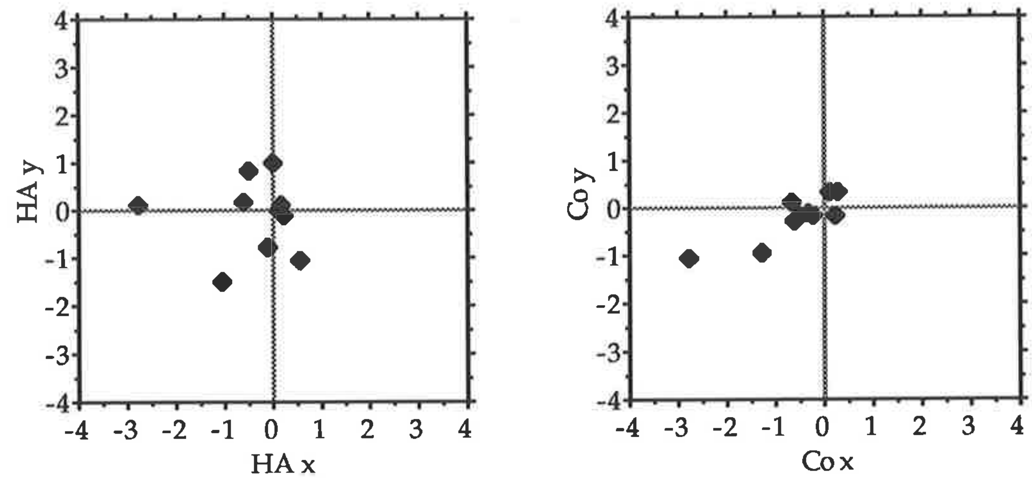



**Figure 10.4: Differences between digitised double determinations for hinge axis (HA) and condylion (Co).**

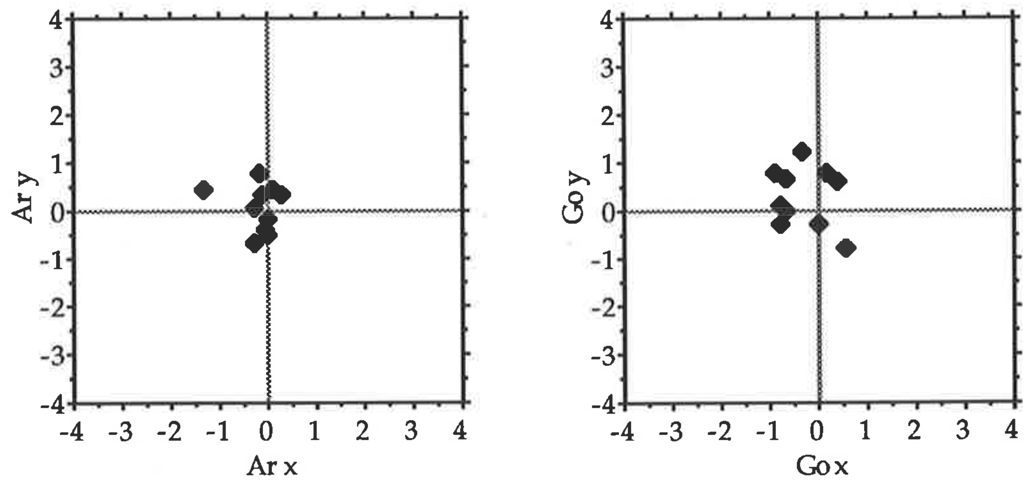



**Figure 10.5: Differences between digitised double determinations for articulare (Ar) and gonion (Go).**

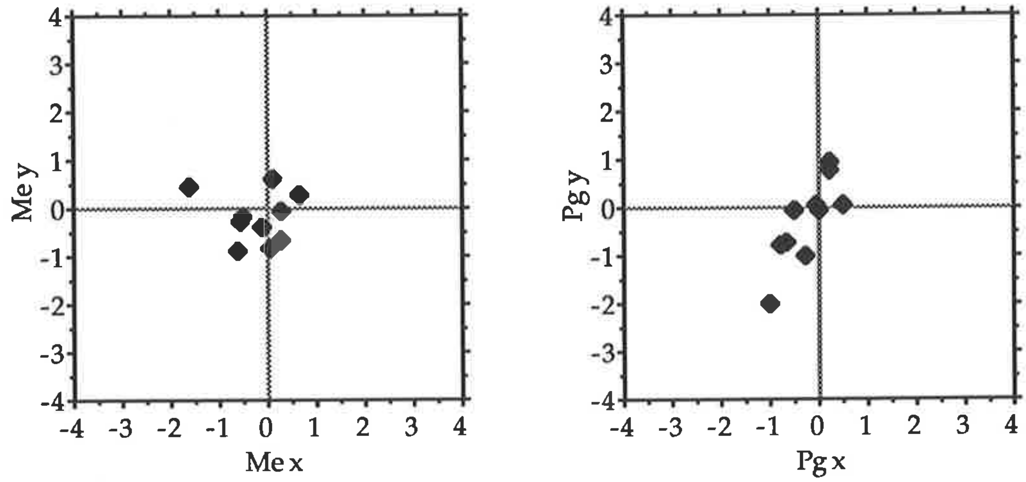



**Figure 10.6: Differences between digitised double determinations for menton (Me) and pogonion (Pg).**

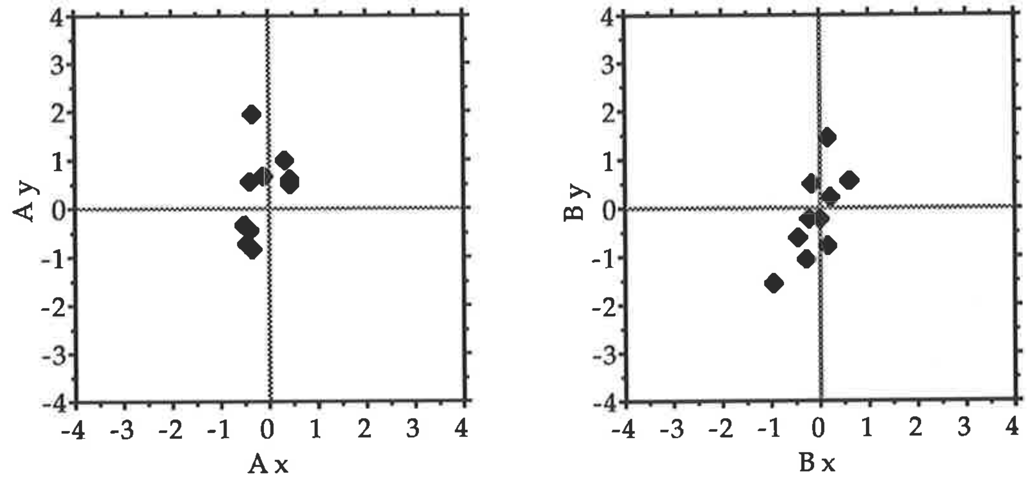



**Figure 10.7: Differences between digitised double determinations for A point (A) and B point (B).**

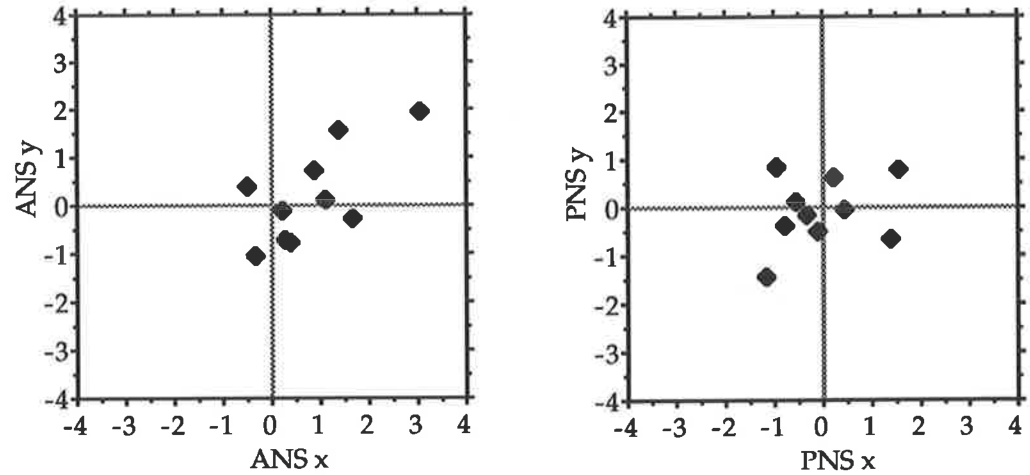



**Figure 10.8: Differences between digitised double determinations for anterior nasal spine (ANS) and Posterior nasal spine (PNS).**

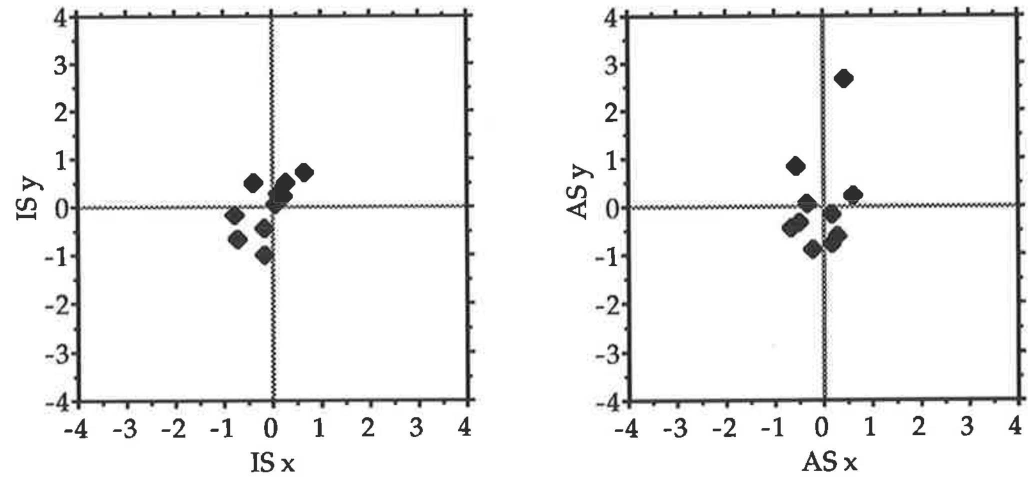



**Figure 10.9: Differences between digitised double determinations for upper incisal tip (IS) and upper incisal apex (AS).**

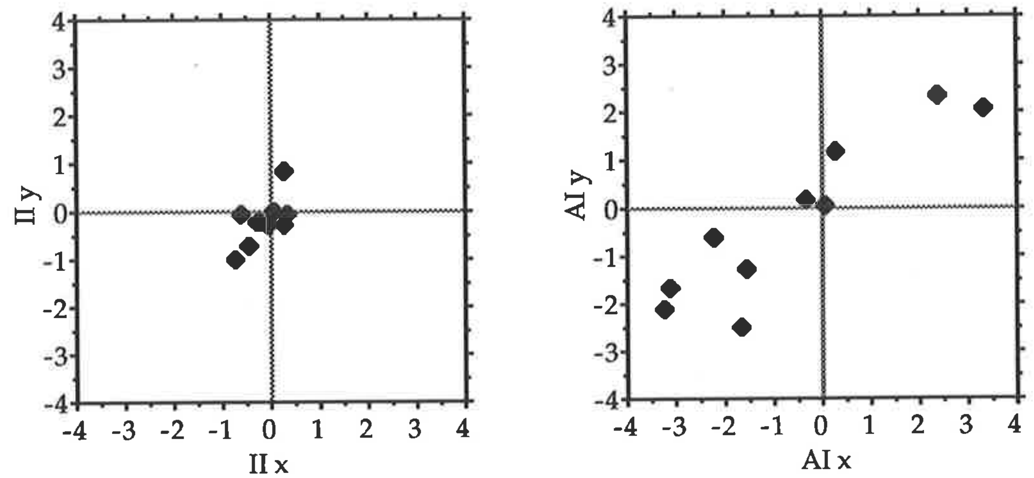



**Figure 10.10: Differences between digitised double determinations for lower incisal tip (II) and lower incisal apex (AI).**

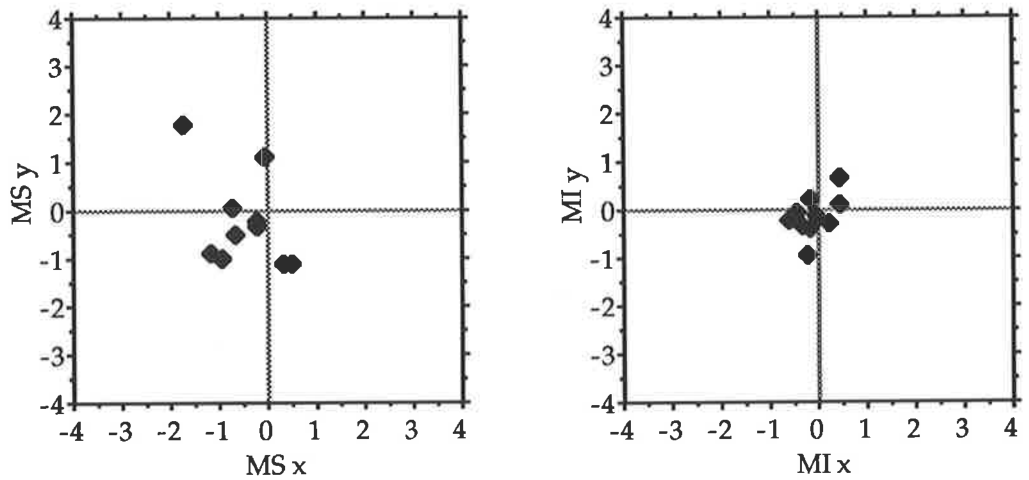



**Figure 10.11: Differences between digitised double determinations for upper molar crown (MS) and lower molar crown (MI).**

*10.2 ERRORS FOR LINEAR AND ANGULAR VARIABLES*

Table 10.3 summarises the total errors for 13 angular and linear variables expressed as the mean differences, the standard error of the mean differences, minima, maxima, the standard deviation of a single determination and the error variance per cent. With the exception of IMPA and overbite, the percentage of error variance was low and did not exceed 3%. None of the mean differences exceeded a value of 0.5. The angles from 0.1 to 0.5° whilst the linear measurements varied from 0.1 to 0.3 mm.

**Table 10.3. Total errors of the method for thirteen angular and linear variables (N = 20 double determinations)**

| Variable | M diff | E (M diff) | Min. | Max. | S (error) | % E var. |
|---|---|---|---|---|---|---|
| SNB | -0.2 | 0.07 | -0.9 | 0.2 | 0.27 | 0.65 |
| SNArGo | 0.3 | 0.12 | -0.7 | 1.7 | 0.49 | 0.99 |
| ArGoMe | 0.1 | 0.19 | -1.9 | 1.5 | 0.56 | 1.06 |
| SNGoMe | 0.3 | 0.12 | -0.6 | 1.2 | 0.43 | 0.40 |
| 1-SN | 0.5 | 0.35 | -2.4 | 2.8 | 1.07 | 1.83 |
| IIA | -0.5 | 0.51 | -3.6 | 2.9 | 1.54 | 2.23 |
| IMPA | 0.1 | 0.53 | -4.3 | 4.3 | 1.54 | 5.10 |
| PFH | -0.1 | 0.12 | -1.2 | 0.6 | 0.36 | 0.27 |
| AFH | 0.1 | 0.08 | -0.7 | 0.7 | 0.23 | 0.10 |
| Gon. Arc | 0.3 | 0.12 | -0.7 | 1.0 | 0.40 | 0.56 |
| SN-7⊥B | -0.2 | 0.13 | -1.1 | 0.5 | 0.34 | 0.21 |
| OJ | 0.0 | 0.13 | -1.3 | 0.7 | 0.37 | 2.07 |
| OB | -0.1 | 0.18 | -1.0 | 1.7 | 0.53 | 4.69 |

### 10.3. COMPARATIVE ERRORS FOR COMPUTER AND MANUAL MENSURATION

Table 10.4 summarises the results of a comparison between computer and manually derived values. Of the nine angles, five were found to differ significantly, four for $P \leq 0.01$ and one for $P \leq 0.05$. Two of the linear values differed at the 5% level of probability. However, the mean differences and standard error of the mean differences were small and none of the angles or distances exceeded 1° or 1 mm for the standard deviation of a single determination. The percentages of the observed variance attributable to errors were low for all angular variables. Of the linear variables, overjet and overbite displayed the largest values of 4.52% and 2.55% respectively.

**Table 10.4. Analysis of differences between computer and manual measurements for 13 angular and linear variables (N = 50)**

| Variable | M diff | E (M diff) | Min. | Max. | S (error) | % E var. |
|---|---|---|---|---|---|---|
| SNA | -0.10 | 0.07 | -0.80 | 1.40 | 0.35 | 1.71 |
| SNB | -0.20 | 0.06 | -1.00 | 0.60 | 0.30 | 0.99 |
| NAFH | -0.30 | 0.06** | -1.10 | 0.70 | 0.35 | 1.55 |
| NPgFH | -0.40 | 0.05** | -1.50 | 0.30 | 0.37 | 1.36 |
| MPFH | -0.40 | 0.06** | -1.20 | 0.60 | 0.38 | 0.62 |
| SNMP | -0.50 | 0.06 | -1.90 | 0.30 | 0.45 | 0.48 |
| 1-SN | 0.10 | 0.13 | -2.10 | 2.20 | 0.65 | 1.17 |
| IIA | -0.30 | 0.13* | -2.70 | 1.50 | 0.66 | 1.09 |
| IMPA | 0.60 | 0.10** | -0.80 | 2.10 | 0.66 | 0.99 |
| SN | -0.20 | 0.07 | -2.30 | 0.70 | 0.39 | 0.12 |
| GoM | -0.30 | 0.14* | -3.20 | 2.10 | 0.71 | 0.51 |
| OJ | -0.30 | 0.14* | -3.00 | 1.60 | 0.71 | 4.52 |
| OB | -0.30 | 0.08 | -1.90 | 0.80 | 0.46 | 2.55 |

DF = 49
* = $P \leq 0.05$
** = $P \leq 0.01$

# V

# Discussion

# CHAPTER 11

## DISCUSSION
## SELECTION OF PATIENT RECORDS

Seventy case records were retrieved from the surgical files of the Oral and Maxillofacial Surgery Unit, The University of Adelaide. However, thirty (43%) were excluded from the study either because the records did not meet the postsurgical criteria or because adjunctive surgical procedures had been performed. The lack of complete radiographic records illustrates an inherent disadvantage with retrospective studies. Incomplete data is a major problem even when an institutional protocol for data collection exists. Records were frequently misplaced, not requested postsurgically by the surgeon or orthodontist, requested but not taken, or the patient was lost to followup.

This last factor was influenced by socioeconomic factors since many of the school students and the unemployed in this study moved from Adelaide in order to pursue further studies or work opportunities. Some patients were unable to devote their time to post-treatment review because of work commitments. A small number of patients (3) were pregnant at the time of recall and did not wish to submit to radiographic examination.

It was evident from this study that data collection tasks are inconvenient and subject to inconsistencies particularly where several members of staff are involved in patient management. We found that when record gathering duties were assigned to one person, the continuity of record keeping improved dramatically. Computerisation of hospital patient files offers the prospect of efficient radiographic review if automatic patient recall is available. This will improve the nature of retrospective and prospective clinical studies.

Computerised storage of cephalometric radiographs is considered to be an attractive option (Harradine and Birnie, 1985). However, storage of cephalograms by digitising procedures cannot be recommended for research unless inter-observer error can be eliminated. This is highly improbable in a multiuser institution. Even when rigid cephalometric definitions are applied, the individual observer's interpretation of the definition remains one of the main factors in inter-observer error (Stabrun and Danielsen, 1982; Savage et al., 1987). Therefore the continued acquisition of suitable radiographic files and protective storage remain the only worthwhile means of ensuring valid retrospective studies. Large volume storage media such as microfiche may be an alternative if magnification factors can be standardised.

The selected sample ranged from 13.0 to 27.8 years of age with a mean age of 19.2 years. Bone age could not be confirmed in this retrospective study as hand-wrist films were not taken at the time of surgery. These would have provided a more reliable guide to developmental status than chronological age (Brown et al., 1971). Therefore, the stability of the distance sella-nasion was used as a guide to skeletal maturity with its attendant limitations. Two male patients were discarded from the study as they showed measurable gains in sella-nasion length.

A comparison with untreated patients matched for skeletal maturation, sex and dentoskeletal pattern may have provided a clearer indication of the effects of growth. However, this would present logistic problems since the number of patients who present for surgery is only a small proportion of the general population. Matching untreated patients with treated patients could prove difficult given the limited pool of patients who are eligible to attend the Adelaide Dental Hospital.

Female patients outnumbered males in a ratio of almost 3:1. Most orthognathic studies show a higher proportion of females undergoing surgery, a consistent finding which appears to be associated with greater aesthetic and functional concerns (Kiyak et al., 1984; Flanary et al., 1985).

This is the first thesis to use material based on the surgical population from the Oral and Maxillofacial Surgical Unit, The University of Adelaide. With the addition of further cases, particularly male subjects, comparisons against non-surgically managed orthodontic patients may provide valuable insight into the management of mandibular hypoplasia.

# CHAPTER 12

# DISCUSSION
# FACTORS IN EARLY RELAPSE

The results of this study showed that there were no significant differences between sexes for any of the variables studied. When the groups were examined according to the method of fixation, relatively minor differences between the screw (SF) and wire (WF) fixation groups were evident in the first 6 weeks following surgery.

## *12.1. MAGNITUDE OF ADVANCEMENT*

Relapse appeared to be associated with the amount of surgical advancement and is in agreement with Lake et al. (1981), Will et al. (1984), Smith et al. (1985), Van Sickels and Flanary (1985) and Wade (1988). A moderate correlation was recorded ($r = 0.521$; $P < 0.005$) but this correlation requires careful interpretation.

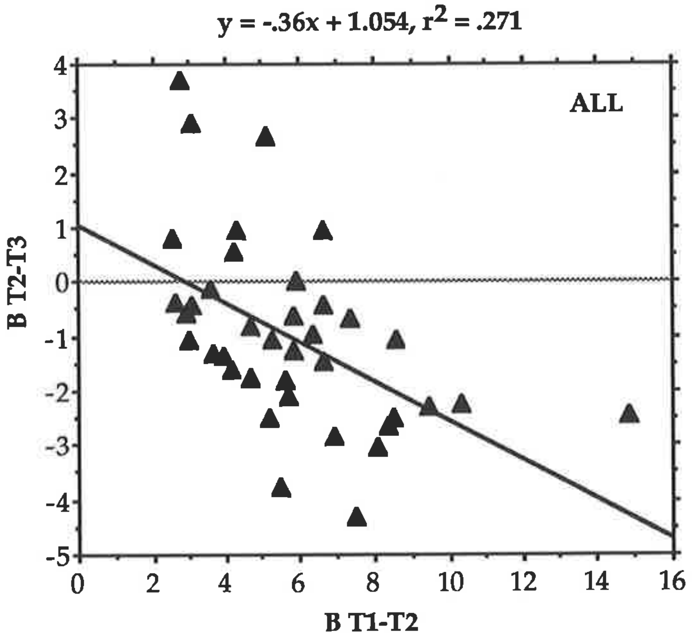



**Figure 12.1: Correlation between advancement at B point and backward movement at B point after 6 weeks (N = 40).**

Brown (1973) and several other authors (Croxton, 1953; Garn and Shamir, 1958; Björk and Solow, 1962; Solow, 1966; Peck and Peck, 1980) have commented that misleading correlations may arise from variables sharing the same components, topographical association, or through the commonality of the reference line. Notwithstanding the presence of a "specious association", a true biological effect could still exist (Brown, 1973).

Solow (1966) considered that topographical associations arose between two variables wherever there were common reference points, lines or angles. The use of the SN-7 line and the SN-7 perpendicular as a common reference system meant that topographical correlations were unavoidable in this study. Furthermore, Björk and Solow (1962) found that correlation coefficients were overestimated when variables shared the same landmarks. Therefore, in assessing the relationship between magnitude of advancement and relapse, a moderate to high correlation coefficient would be expected for changes at B point independent of a true biological effect. When relapse was expressed as a percentage of the advancement the $r$ value was low (0.287; $P < 0.10$) confirming the findings of Ive et al. (1977) and Lake et al. (1981).

### *12.2. CONDYLAR DISPLACEMENT*

This study did not show a clear association between condylar displacement and early relapse tendency. This is in agreement with Will et al. (1984) and Smith et al. (1985) but differs from Kohn (1978) and Lake et al. (1981). Lake et al. (1981) were able to show a moderate correlation ($r = 0.5$; $P < 0.001$) between gonial arc radius and relapse at pogonion but no relationship was found ($r = 0.068$) in this study. Our studies showed that gonial arc radius increased for both groups in 26 of the 40 (65%) cases but returned by 6 weeks, including those patients in intermaxillary fixation.

This observation of condylar return has been reported by others (Kohn, 1978; Lake et al., 1981; Smith et al., 1985). Assessment of the data (Table 8.4, p.137) showed that early relapse was independent of gonial arc radius although in individual cases, such as the long term female in group 1

(BSSA, SF), the converse was true. However, the fact that condylar distraction occurred perioperatively in 65% of the patients is disturbing and deserves comment.

The causes of condylar distraction are not clear. Lake et al. (1981) listed several possibilities in his article. These were failure to correctly reposition the condyles at surgery; gradual condylar displacement due to soft tissue pull; remodelling or resorption of the condylar heads; and altered intersegmental relationship secondary to ineffective fixation or fibrous union.

One possibility which has not been mentioned is that there may be only an apparent condylar shift. When patients have their preoperative lateral head cephalogram, their condyles may not be correctly positioned because of occlusal deflections, elastic traction or jaw posturing. The lack of proper occlusal interdigitation is a frequently observed inconvenience of orthodontic decompensation prior to surgery. Therefore, the true condylar relationship may not be recorded faithfully. As a consequence, the T1-T2 radiographic comparison may have errors in jaw position which may not be readily apparent and are cephalometrically misinterpreted.

Our study recorded several cases where the gonial arc radius decreased 1 to 2 mm. This could be due to either aggressive use of force during wire or screw application (Nickerson, 1983) or cephalometric error. If the former were true, one would anticipate a reduction in relapse as the compressed capsular tissues resume their normal shape. None of the cases with 1 to 2 mm reduction in gonial arc had low relapse. Therefore cephalometric misinterpretation of condylar position and errors associated with the location of gonion and hinge axis are quite probable.

Improper condylar position is considered by many to be a major factor in relapse (Isaacson et al., 1978; Kohn, 1978; Schendel et al., 1978; MacIntosh, 1981; Schendel and Epker, 1980; Lake et al., 1981; Epker and Wessberg, 1982; Sandor et al., 1984, Hase, 1988). Despite a surgical preoccupation with condylar location, effects related to muscle relaxant, intracapsular oedema (Wade, 1988) and tissue tension (Will et al., 1984) may interfere with meticulous attempts at manual manipulation of the proximal segment. McMillen (1972) showed that when muscle relaxant was administered, the condyles dropped from the glenoid fossae and could not be repositioned into their preanaesthetic position.

The problem has not been solved with condylar locating devices (Leonard, 1976; Zecha et al., 1978; Leonard, 1985; Luhr, 1985; Raveh et al., 1988) although in principle, they appear to offer a promising solution. In deference to McMillen's findings (1972), Raveh et al. (1988) have stressed the reproduction of the true preoperative centric relation in distinction to the apparent centric relation established under general anaesthesia. They use an intraoperative wafer which reproduces the presurgical centric relation found in the conscious state. A condylar locating device is subsequently attached to the ascending ramus prior to the sagittal split osteotomy. This logical progression may hold the key to reducing relapse attributable to condylar distraction.

### *12.3. FACIAL HEIGHT*

Partial loss of the initial increase in anterior facial height is considered to be a reflection of early relapse. However, sustained increases are universally reported (White et al., 1971; Ive et al., 1977; Kohn, 1978; Lake et al., 1981; Will et al., 1984; Van Sickels et al., 1988). None of the cases which had single jaw (mandibular) surgery in this study had surgically decreased anterior facial height. Several bimaxillary cases decreased as a result of maxillary impaction but they had net increases in lower facial height. Surgically decreased anterior facial height and increased posterior facial height in single jaw surgery have been related to early relapse because they represent anticlockwise rotation of the mandible. Most attention has concentrated on increased posterior facial height as an entity in relapse.

Kohn (1978), Schendel and Epker (1980) and Lake et al. (1981) found that surgically increased posterior facial height and increased gonial arc radius contributed to relapse. No such relationship was found in this study. The similarity between these two variables was confirmed by their high correlation value ($r$ = 0.938). Both variables ultimately assess condylar distraction since gonion is used in both instances and therefore, are topographically associated. This point is illustrated by the results of Will et al. (1984). They showed that *decreased* posterior facial height during fixation correlated with early relapse ($r$ = 0.81). However, this may not have been a true decrease in posterior facial height. It merely re-expresses surgically increased gonial arc radius since gonion is located on the proximal segment.

In retrospect, there may have been merit in using a point which resides on the distal segment, such as lower border point (Smith et al., 1985). This would give a better estimation of altered posterior facial height in the distal segment and indicate whether anticlockwise rotation has occurred.

### *12.4. MANDIBULAR PLANE ANGLE*

Although the preoperative mandibular plane angle has been related to relapse, no significant differences in postoperative relapse were shown for any of the groups when categorised into high or low preoperative mandibular plane angle (Table 8.8, p.141). An angle of 37° was used as this was the upper limit of normal adopted by the Adelaide Oral and Maxillofacial Surgical Unit. Kohn (1978) cited the work of Riedel (1952) who established that the normal value for the mandibular plane angle was 32° with a range of 27° to 37°, equivalent to one standard deviation. Lake et al. (1981) selected a similar value and found that higher angle cases were subject to greater relapse but overall, mandibular plane angle was only weakly correlated with relapse. In their 6 week study, Ive et al. (1977) concluded that there was no distinguishable pattern relating relapse with the mandibular plane angle.

### *12.5. METHOD OF FIXATION*

Both groups had comparable mean mandibular advancement but the relapse tendency was higher in the SF group (-20.3%). This level of relapse conflicts with previous investigations on the stability of screw fixation (Van Sickels and Flanary, 1985; Van Sickels et al., 1988). The magnitude of advancement and the operative technique were comparable to other studies using screw fixation.

It has been argued that lag screws may displace the condyle from the fossa if improperly applied (Rittersma et al., 1981; Nickerson, 1983; Sandor et al., 1984). However, our unit has been using bicortical non-compression screw fixation which is less likely to distract the joint since the bone segments are held in a passive relationship. The use of a bone clamp to temporarily stabilise the segments is also discouraged as its use has been associated with iatrogenic posterior open bite (Jeter et al., 1984; Muller and Bach, 1989) and condylar torquing (Raveh et al. 1988). Since our sample size was limited, prospective studies should demonstrate whether this trend towards relapse becomes less pronounced. It is apparent that the early postoperative period remains an important time for postsurgical evaluation.

Early relapse in the WF group was -13.6% but this difference compared with the SF group did not reach statistical significance. The amount of relapse in the WF group compares favourably with the literature (Table 12.1). Early relapse figures range from -19% (Wade, 1988) to -45% (Will et al., 1984). This suggests that some relapse is inevitable when upper border wiring is used and consideration should be given to overcorrection during surgical planning.

**Table 12.1. Relapse % in the early postoperative phase.**

| Author | Year | Patients | Method | % Relapse |
|---|---|---|---|---|
| Ive et al. | 1977 | 21 | UBW | -30 |
| Kohn, | 1978 | 17 | UBW | -17 |
| Lake et al. | 1981 | 52 | UBW | -19 |
| Sandor et al. | 1984 | 20 | UBW | -10 |
| Will et al. | 1984 | 41 | UBW | -45 |
| Wade | 1988 | 12 | UBW | -19 |
| Van Sickels et al. | 1988 | 51 | Screws | -1.3 |

***Method of fixation:** UBW: Upper border wiring and intermaxillary fixation
Screws: Bicortical screw fixation

The most significant difference ($P < 0.005$) between the fixation groups was the surgical increase in gonial angulation for the WF group. This was almost double the change recorded for the SF group. Singer and Bays (1985) related this loss of the gonial angle to rotation of the proximal segment and commented that this may present aesthetic concerns. In reviewing our results, proximal segment rotation (ramal angle) occurred in both groups but the change was relatively small. The increase in gonial angle for the WF group related more strongly to increased anterior facial height with a lesser contribution from proximal rotation. Freihofer and Petresevic (1975) noted that increased gonial angle was associated with relapse however, we were unable to demonstrate a correlation.

Interestingly, dental compensation during the first six weeks (T2-T3) was not conspicuous in either group. This is probably due to the stability of presurgical orthodontics and is consistent with the improved understanding of presurgical requirements. At least one study (McNeill et al., 1973) has reported that retroclination of maxillary incisors and proclination of mandibular incisors occurs during intermaxillary fixation. When this occurs, early skeletal relapse is masked, giving a deceptive clinical impression of surgical stability.

A statistical difference in relapse was not shown between the fixation groups indicating that screw fixation did not confer any advantages in terms of early stability. In view of the finding that condylar position was not a primary determinant of relapse, it would appear that other factors encourage early relapse. Freihofer and Petresevic (1975) felt that surgical experience did not influence relapse. This would be difficult to verify or disprove in this study since most osteotomies were usually performed by both a consultant and registrar surgeon. Nevertheless, the introduction of a new surgical technique, such as screw fixation, inevitably involves a learning phase where intraoperative compromise may occur. Thus the consequences of accepting small compromises in occlusion may not be apparent until cephalometric studies are embarked upon.

The WF group may have demonstrated good early results for two reasons. Firstly, upper border wiring has been the method of choice for many years, therefore experienced surgeons are familiar with the minutiae of the technique. Secondly, small discrepancies in position can be compensated for during fixation, by movement at the osteotomy since osteosynthesis wires do not rigidly secure the segments.

This latter explanation is less plausible but was raised as a possibility by Isaacson et al. (1978). He favoured the omission of transosseous osteosynthesis, arguing that the segments would be free to assume a biologically stable position. The logic of his argument was discounted by the finding of Finn et al. (1980). They described the accentuated "force coupling" at the osteotomy site following mandibular advancement. The authors maintained that proximal segment rotation radically altered the masticatory muscle pull thereby changing the biomechanical lever arm. Unless this so-called "force coupling" could be controlled, then relapse was very likely to occur. Will et al. (1984) felt that this simplified biomechanical concept of a complex mechanism disregarded the neuromuscular physiology and the process of adaptation suggested by Wessberg and Epker (1981).

### *12.6. MUSCULAR INTERACTIONS*

The resistance from paramandibular soft tissues (Epker and Wessberg, 1982) appears to be one of the most logical explanations for early relapse. However, controversy persists regarding the merits of suprahyoid myotomy (Poulton and Ware, 1971; McNeill et al., 1973; Steinhauser, 1973; Guernsey, 1974; Epker et al., 1978; Schendel and Epker, 1980; Epker and Wessberg, 1982; Wessberg et al., 1982; Carlson et al., 1987) or division of the periosteum as proposed by Guernsey (1974). Our unit does not routinely perform suprahyoid myotomy or wide periosteal stripping during mandibular advancement so we are unable to comment on their efficacy. There is no doubt that the influence of the soft tissues, either through neuromuscular mechanisms or through physical resistance, are responsible for some of the early skeletal relapse.

# CHAPTER 13

# DISCUSSION
## FACTORS IN INTERMEDIATE AND LONG TERM RELAPSE

This study confirmed the findings of previously published research that mandibular relapse continued into the intermediate period. Kohn (1978) and Sandor et al. (1984) both observed that relapse continued many months postoperatively. Relapse in the long term was far less noticeable, an effect which has been described by Poulton et al. (1979), Lake et al. (1981) and Lello (1987). The data from this study showed a mean percentage relapse of -32% in the first 12 months.

Approximately half of the relapse (-17%) occurred in the first six weeks and the remainder occurred over the next ten months. Previous studies documenting relapse with wire osteosynthesis have indicated the incremental progression of relapse (Table 13.1).

**Table 13.1: Relapse % in the intermediate and long term.**

| Author | Year | Patients | Method | Period (mo.) | % Relapse |
|---|---|---|---|---|---|
| Poulton & Ware | 1971 | 3 | UBW | 6 | -23 - -44 |
| Poulton & Ware | 1973 | 8 | UBW | 9-43 | -10 - -30 |
| Freihofer & Petresevic | 1975 | 118 | UBW | 24-60 | -10 - -60 |
| Kohn | 1978 | 17 | UBW | 6-24 | -49 |
| Isaacson et al. | 1978 | 3 | IMF only | 9-12 | -43 |
| Lake et al. | 1981 | 52 | UBW | 42 | -25 |
| Sandor et al. | 1984 | 20 | UBW | 12 | -23 |
| Wade | 1988 | 12 | UBW | 24 | -27 |
| Van Sickels et al. | 1986 | 19 | Screws | 6 | <-5 |
| Kirkpatrick et al. | 1987 | 20 | Screws | 6 | -8 |
| Van Sickels et al. | 1988 | 51 | Screws | 6 | <-5 |

***Method of fixation:** UBW: Upper border wiring and intermaxillary fixation
Screws: Bicortical screw fixation

Kohn (1978) observed -17% relapse within 2 months of surgery and a further -32% relapse after a minimum of 6 months. Sandor et al. (1984) measured -10% relapse in the first six weeks and a further -13% by 12 months. Wade (1988) found that -19% of the advancement had been lost after 6 weeks and a further -7% by 24 months. Screw fixation studies have indicated that whilst relapse occurs, the magnitude is far less than wire fixation. Most reports based on 6 month reviews (Van Sickels et al., 1986; Kirkpatrick et al., 1987; Van Sickels et al., 1988) document mean relapse rates which do not exceed -8%.

In the long term, stability was observed for all variables. A small forward movement at B point (+2%) was observed in the second postoperative year for the wire fixation group. This effect has also been reported by Lake and his colleagues (1981) who found that there was a mean increase of 3 per cent in the long term post-fixation phase. Long term relapse was not correlated with surgical advancement. Notwithstanding the topographical relationship between B T1-T2 and B T2-T5, the correlation was weak for pooled patients and for individual fixation groups. Since none of the variables in this study changed significantly in the second year confirming the stability of the osteotomy after 12 months, it appears that 12 month's observation is a minimum requirement for long term studies.

### *13.2. MAGNITUDE OF ADVANCEMENT*

In common with the conclusions of Lake et al. (1981), Smith et al. (1985) and Van Sickels and Flanary (1985), intermediate relapse appeared to be correlated with the amount of surgical advancement in the mandible ($r$ = 0.446;
$P < 0.005$; Figure 13.1) when all subjects were included. This association was slightly stronger in the wire fixation group compared to the screw fixation group.

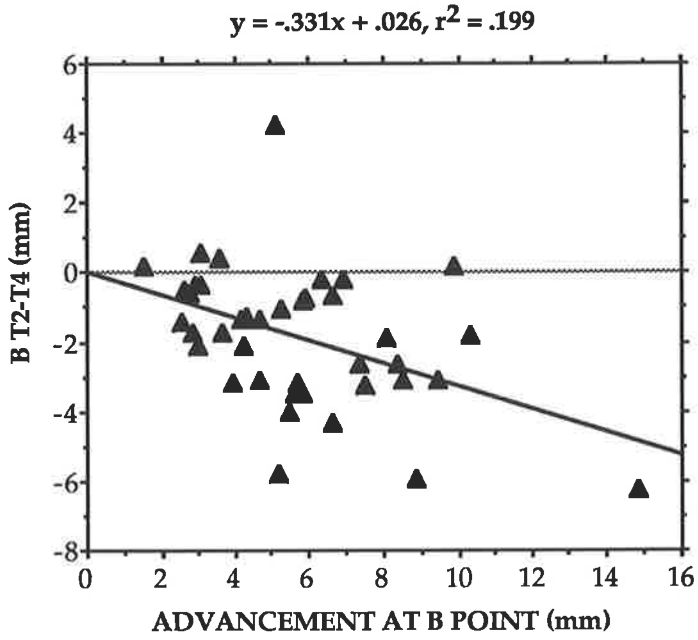



**Figure 13.1: Correlation between advancement at B point and backward movement at B point after 12 months (N = 40).**

The "specious" nature of the correlation between magnitude of advancement and movement at B point has previously been discussed in the section on early relapse. With the benefit of increased sample size, clarification of this relationship may emerge. Nevertheless, a biological effect appeared to be involved, supporting the contention that the greater the initial surgical advancement, the greater the likelihood of postsurgical relapse within one year.

### *13.3. CONDYLAR POSITION*

No correlation with gonial arc radius and intermediate or long term relapse was shown by the sample. Although the long term screw fixation group showed a moderate correlation of 0.406 with percentage relapse, there were only 4 subjects, invalidating any worthwhile comment. Lake et al. (1981) came to a similar conclusion and felt that the effect of condylar position was limited to early relapse. Kohn's results (1978) contrast with the findings of this study. He reported that long term relapse was correlated with surgically increased gonial arc radius. This difference in correlation does not have a straightforward explanation and reinforces the multifactorial etiology of relapse (Lake et al., 1981). Kohn's study was based on a smaller sample of 12 patients which could explain the different patterns.

### *13.4. FACIAL HEIGHT*

Studies by Van Sickels et al. (1986) have shown that surgically increased anterior facial height is not fully maintained over time. Our results supported this finding with a 49% loss of the original gain. The loss occurred in equal proportion between the periods T2-T3 and T3-T4. Very little change occurred in the long term. One reason for this large decrease was that the majority of our patients required postsurgical extrusion of the posterior teeth to preserve lower facial height (Stoelinga and Leenen, 1981a, 1981b). Since our results showed that over half the skeletal relapse occurred in the first 6 weeks when orthodontic therapy was suspended, considerable loss in anterior facial height would already have resulted. The continued loss of anterior facial height indicated that dentoskeletal changes continue into the intermediate period.

Posterior facial height did not alter markedly at any stage with the net result being a small decrease of -1.1 mm after 12 months. This observation explains the low correlation with intermediate relapse. Most studies have shown that increases in posterior facial height are unstable and that decreases in posterior facial height are usually seen long term (Lake et al., 1981; Greebe and Tuinzing, 1984; Van Sickels et al., 1986). There was no evidence in this study that surgically altered posterior facial height contributed to relapse in the intermediate or long term.

### *13.5. PREOPERATIVE MANDIBULAR PLANE ANGLE*

The preoperative mandibular plane angle has been cited as a predictor of relapse (Kohn, 1978). In this investigation, correlation values for mandibular plane angle and relapse per cent were low for all intervals. A correlative effect ($r$ = 0.427) was demonstrated between mandibular plane angle and movement at B point for the screw fixation group (Figure 13.2). However, this changed to a negative correlation when patients with mandibular plane angles below 37° were excluded (Figure 13.3). The most important point made by Lake et al. (1981) was that presurgical predictions of relapse cannot be based on a single variable such as mandibular plane angle.

Many of the early studies (Poulton and Ware, 1971, McNeill et al. 1973) which cited mandibular plane angle as a relapse factor were apertognathic cases with associated high mandibular plane angles. These cases also had large mandibular advancements which increased the risk of relapse. MacIntosh (1981) has pointed out that apertognathia is a contraindication to sagittal split osteotomy when used as the sole surgical procedure. This is due to the unfavourable soft tissue stretching created by anticlockwise rotation of the distal segment and a proprioceptive drive to reassume the preoperative equilibrium.

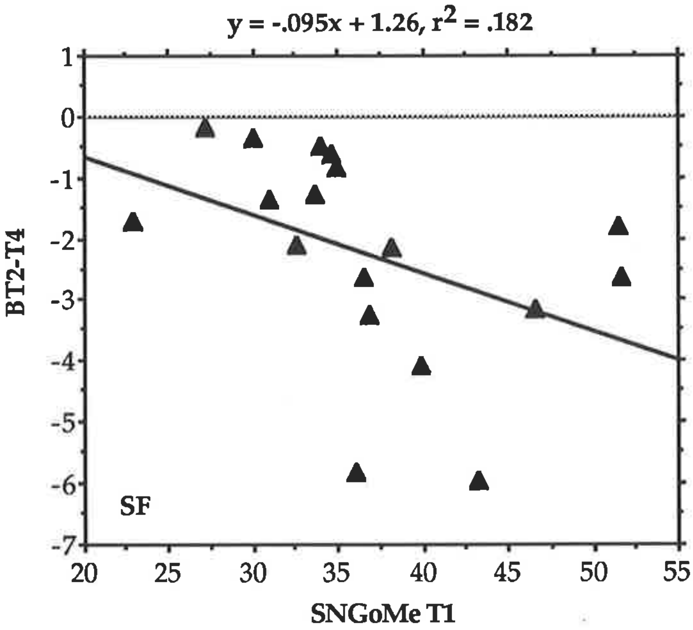



**Figure 13.2: Correlation between preoperative mandibular plane angle and postoperative movement at B point during the first 12 months for the screw fixation group (N = 18).**

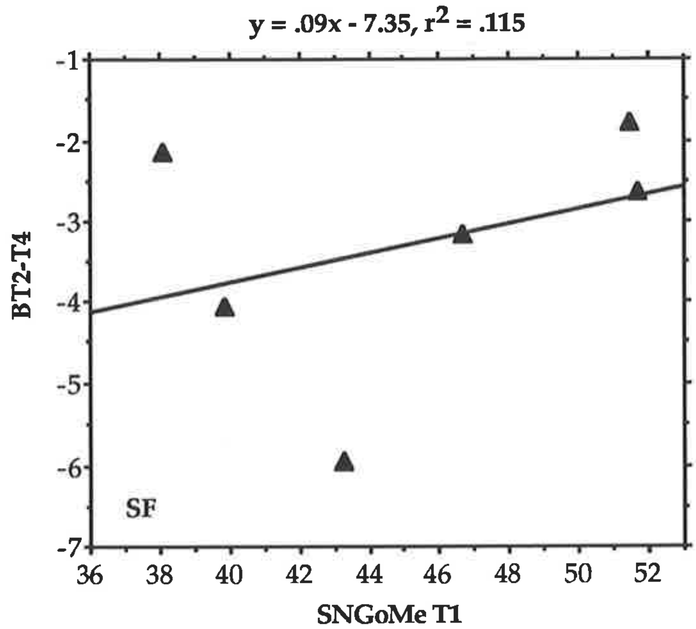



**Figure 13.3: Correlation between preoperative mandibular plane angle (> 37°) and movement at B point during the first 12 months for the screw fixation group (N = 6).**

Ive et al. (1977) avoided anticlockwise rotation by performing bimaxillary procedures with posterior maxillary impaction where mandibular hypoplasia and apertognathia coexisted. Brammer et al. (1980) found that posterior maxillary impaction in conjunction with bilateral split advancement correlated well with decreased relapse.

Finn et al. (1980) used a high angle biomechanical model to explain the improved stability of bimaxillary cases. They postulated that decreased muscle activity resulted in fewer disruptive forces on the proximal segment. Our data (Table 8.9, p.142) showed that there was a trend towards less relapse for bimaxillary cases but this was not statistically significant. High mandibular plane angle cases tended to have more relapse than low angle cases but none of these differences were statistically significant. In this study, the groups were too small for valid comparison and each differed in the magnitude of advancement. Larger surgical samples may show that bimaxillary procedures add to postoperative stability and support the concepts of Finn and his colleagues.

### *13.6. METHOD OF FIXATION*

Relapse was not appreciably different between the fixation groups in the intermediate and long term. The screw fixation group averaged -37.0% relapse at 12 months and the wire fixation group -27.1%. Intermediate relapse in the wire fixation group is consistent with the mean values quoted in the literature. Sandor et al. (1984) observed relapse of -23% one year after operation whilst Kohn (1978) recorded -32% a minimum 6 months postsurgery.

The relapse rate of -37% in the screw fixation group is much greater than values reported in the literature which are typically less than -10% (Van Sickels et al., 1986; Kirkpatrick et al., 1987; Van Sickels et al., 1988). The reasons for this difference is not clear particularly as the magnitude of advancement in our study was comparable. It is possible that the relative surgical inexperience with screw fixation may have contributed to the greater relapse tendency. However, one would anticipate this to be a universal problem and would therefore be reflected throughout the international literature. Unique patient population or different orthodontic therapy may have influenced relapse although the similarity of our results in the wire fixation group when compared with the literature tends to cast doubt on this assertion.

In cases which experienced relapse, the skeletal change was clinically masked by postsurgical orthodontic therapy. Maxillary incisal retraction ranging from -1° to -8.9° was noted for the bilateral sagittal split osteotomy patients. The interincisal angle increased accordingly. Lower incisal angle was not a reliable guide since the position of gonion altered the mandibular plane angle. The bimaxillary cases had slightly less maxillary incisal retraction and decreased interincisal angle. This demonstrated that whilst the occlusion remained clinically acceptable, facial aesthetics were at risk due to skeletal relapse.

### *13.7. BONY HEALING*

The site of relapse has logically been regarded as the osteotomy sites. However, Will and her associates (1984) commented on the cephalometric stability of the gonial angle after six weeks of healing. In our study, gonial angle remained remarkably stable throughout the observation period, even during the first six weeks. Moderate changes in ramal angle occurred at surgery but there was only a few degrees change in the ensuing 12 months. This anticlockwise movement would not account for the relapse and in fact, would counteract a backward displacement of the mandible. Posterior facial height remained constant during the T3-T4 period and there were insignificant changes in gonial arc radius or mandibular plane angle. It would therefore appear that the direction of relapse is parallel to the mandibular plane with shortening in the body of the mandible. However, Wade (1988) has described the use of tantalum markers to assess dimensional change across the osteotomy site. He found that there was no detectable change in 7 of his cases and less than 0.5 mm in the other 5 patients. It seems most likely that a small change in each of the factors cumulatively results in the horizontal relapse observed at B point.

### *13.8. THE EFFECT OF AGE AND SEX*

With the exception of intermediate relapse, the data showed that the sex of the patients did not produce statistically significant differences in any of the cephalometric variables within any of the groups. This is consistent with the presentation of results in the orthognathic literature which generally makes no distinction between male and female patients. Differences between sexes were demonstrated in individual cases. This was particularly true in the long term where the number of cases was low and differences were readily apparent.

In this study, the preliminary results on relapse suggested that males underwent less intermediate relapse despite a similar magnitude of advancement. However, a recognised limitation of this study was the relatively small number of cases. This severely restricts the ability to make valid conclusions regarding variables and their association with relapse.

Notwithstanding this restriction, the trend towards less relapse in males is intriguing. Sexual dimorphism appeared to affect the intermediate relapse tendency and contrasts with the findings of others who have investigated surgical relapse (Freihofer and Petresevic, 1975; Ive et al., 1977; Lake et al., 1981). The male subjects tended to relapse less than females despite a similar magnitude of advancement. The effect appeared to be unrelated to any of the cephalometric variables studied.

In this study, posterior movement at B point in the first 12 months was negatively correlated ($r$ = -0.404) with age for the eleven males (Figure 13.4). The appearance of this interesting trend was quite surprising in view of the common belief that age is not related to relapse (Freihofer and Petresevic, 1975; Lake et al., 1981).

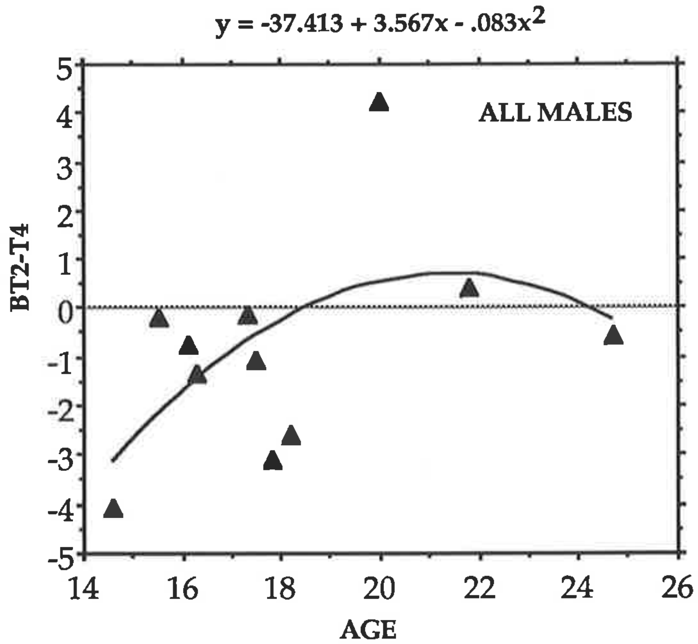



**Figure 13.4: Correlation between age and movement at B point 12 months after surgery for males (N = 11).**

This dimorphic effect may be related to the different maturation characteristics between males and females. The average age for females in this study was 19.8 years compared to 18.1 years for males. Whilst the female patients would have been skeletally mature (Graber, 1969), some growth potential would still be anticipated for the male group. Graber showed that the female facial profile changed most dramatically between 10.5 and 12 years and underwent incrementally smaller changes between 12 and 16 years. The male profile changed most rapidly between 12.5 to 17 years and continued to develop for another 3 or 4 years.

It is postulated that the compensatory effect of growth in this small male sample decreased the impact of postsurgical relapse. A prospective study using a larger series of males may clarify whether this trend represents a true association with decreased relapse tendency. Correlations with skeletal age based on hand-wrist radiographs should be used in preference to chronological age. If this pattern is verified then it may justify earlier surgical intervention than is currently practised.

# CHAPTER 14

## DISCUSSION
## ERRORS OF THE METHOD

The experimental error in this study was comparable to other studies which have investigated method error (Broch et al., 1981; Stabrun and Danielsen, 1982; Farrer, 1984). The error values were similar to Stabrun and Danielsen (1982) who performed double determinations on 100 headplates for 14 hard tissue points. Of the landmarks investigated, they found that apex inferior could not be determined with any certainty in over 75% of their assessments. In this study, and in the study by Baumrind and Frantz (1971a), error values confirmed the poor reliability of lower incisal apex in both planes.

Baumrind and Frantz (1971a) ranked porion as the most reliable point which contrasts with the above results. This difference is most probably due to the different definition of porion since machine porion was used in their investigation. This explanation was also given by the authors and by Vincent and West (1987) who found that anatomical porion was much less reliable and received a much lower ranking.

The problems of accurately identifying structures within the petrous temporal region have been alluded to by Martinoni (1978) and Chate (1987). Anatomical porion may be difficult to locate due to the anatomical complexity of the area, bony structural superimposition, or obscured by the metallic machine porion. Savage et al. (1987) considered anatomical porion to show unacceptable variation. They believe that dimensions based on anatomical porion should be regarded with caution.

In general, points which ranked highly tended to have good edge definition and were least affected by superimposed structures (Baumrind and Frantz, 1971a). Sella and nasion ranked well in this investigation in agreement with studies by Richardson (1966), Baumrind and Frantz (1971a) and Stabrun and Danielsen (1982). The positions of the upper and lower incisal tips were also reproducible. Surprisingly, lower molar crown was reliably located despite the problem of superimposition. This reproducibility may have been due to the presence of an orthodontic band or amalgam restoration which clearly demarcated the distal margin of the lower first molar. On the other hand, although these features were also present for the upper first molar, this point proved to be far less reliable.

Comparison of scattergrams (Figures 10.2-10.11) shows that the distribution of error appeared to follow the pattern observed in other studies, although the range of scatter were not directly comparable. Richardson, (1966), Baumrind and Frantz (1971a), Broch et al., (1981), Stabrun and Danielsen (1982) and Vincent and West (1987) concluded that error is primarily dependent on landmark identification. Richardson (1966, 1981) has remarked that some points, such as sella, are reliable both horizontally and vertically while others, such as Down's B point, are difficult to locate vertically but are quite reproducible horizontally.

Broch et al. (1981) concluded that the characteristics of the skeletal structures are responsible for most of the variations in reproducibility of landmarks. As a consequence, large discrepancies could occasionally occur when performing double determinations. Stabrun and Danielsen (1982) agreed that these gross errors were infrequent and were probably due to film quality and variation in individual anatomy. No large discrepancies were seen in this study for the majority of points. The exception was apex inferior (Figure 10.10) which had a maximum discrepancy of 3.33 mm in the horizontal plane. Several authors have noted that treatment effects based on lower incisal angulation could lead to erroneous conclusions particularly where small changes were involved (Gravely and Murray-Benzies, 1974; Stabrun and Danielsen, 1982).

The Student's t-test showed that none of the differences for any reference point was significant at the 1% level of probability and only two of the values (ANS x and S y) were significantly different from zero at the 5% level. The respective positive and negative patterns (Figure 14.1) for ANS x (anterior nasal spine horizontal) and S y (sella vertical) are not readily explained. These trends would normally be explained by systematic errors particularly if all cephalometric points demonstrated similar patterns.

Systematic errors arising from the digitiser were not examined since Farrer (1984) has established the high precision of the instrument used in this study. The small positive bias in ANS (x) and the small negative tendency for S (y) illustrated in Figure 14.1 was attributed to operator uncertainty rather than machine inaccuracy.

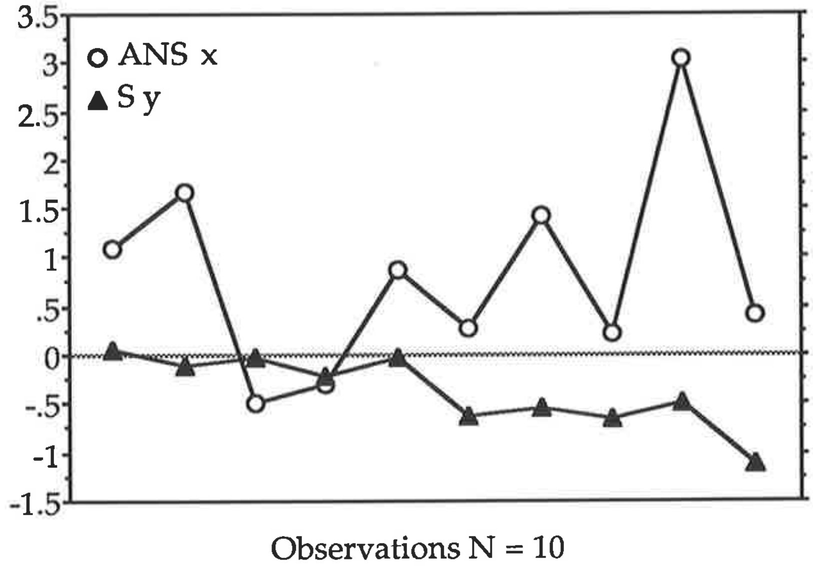



**Figure 14.1: Distribution of differences for ANS x and S y for 10 sets of double determinations.**

The results shown in Table 10.3 (p.179) show that the means of the total error for determining angles and distances were very small. This confirms that when double determinations are performed by the one operator the replicability of points for angles and lines is generally high.

Two exceptions were noted when the % error variance was assessed. The percentage of error variance was relatively large for IMPA and overbite. Because the error associated with the point AI y was high (Table 10.2, p.173), a higher % error variance for any measurement based on this point, such as IMPA, would be anticipated.

However, the high % error variance associated with overbite is due to a different reason. This can be explained by the small distances being measured. Thus a relatively small error in measurement could contribute significantly to the observed variance (Bondevik et al., 1981).

In comparing the accuracy of measurements for hand and computer-derived variables, several of the differences were significant at the 1% level. Review of the raw data showed that there was a definite tendency to underestimate readings compared to the computer. Figure 14.2 illustrates this tendency using the angle NPgFH as a typical example. However, none of the differences were of a magnitude to be clinically significant in orthognathic surgery. Occasionally large differences were noted for several of the linear values and may have arisen by chance. It was also noted that the gradations on the ruler and protractor were not always distinct in the ambient light and may have been incorrectly read.

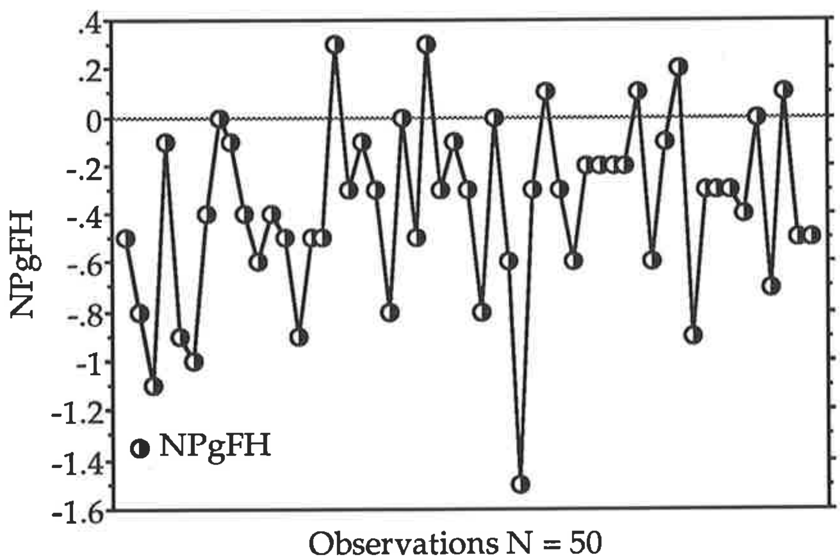



**Figure 14.2: Hand measurements tended to underestimate the angle NPgFH (facial axis) compared to the computer.**

A further source of error with angular variables was associated with the design of the protractor. For angles based on three cephalometric points, a viewing ring in the middle of the protractor was aligned over the intersecting point of the two lines. This ring was large enough that incorrect alignment of the ring over the point could introduce an error.

The data show that angular measurements based on 4 cephalometric points were prone to greater error when derived manually with a protractor. The straight edge of the protractor was aligned and moved along the superior line until the swinging arm intersected the two other points. Accurate alignment could not be guaranteed and was considered largely responsible for the statistical difference seen for the angles NAFH, NPgFH, MPFH and IMPA.

It is clear that the protractor used for this study would be improved by having smaller gradations. Carlsson (1967) recommended increments of 0.1°/mm as he found that the error of measurement was relatively large with 0.5 or 1°/mm intervals. Using the small gradations he reported that the error of measurement was small compared to the error of locating the points. The results of this study support the finding by Carlsson (1967) that small but significant errors may arise from the use of 1°/mm instruments. It would appear that finely graduated rulers and protractors are a necessity where computerised measurement is unavailable.

# VI

# Conclusions

# CHAPTER 15

# CONCLUSIONS

1. The results of this study showed that postsurgical relapse occurred in the short and intermediate term. Cephalometric changes were negligible after one year implying that 12 month's observation is a minimum requirement for long term studies.

2. The validity of these results was confirmed by quantifying the error of the method. Double determinations of ten radiographs showed that the mean differences and total errors of the method were small and contributed less than 2 percent of the observed values. Investigation of the total error for nine angular variables and four linear variables showed that the mean differences and standard error of the mean differences were small and none of the angles or distances exceeded 1° or 1 mm for the standard deviation of a single determination.

3. In general, no statistical differences between sexes or the type of osteotomy (single jaw or bimaxillary surgery) were demonstrated for any of the short or intermediate term variables in this study.

4. When early relapse was examined according to the method of fixation, no correlation was found with the preoperative mandibular plane angle, altered posterior facial height, gonial angle or changes in gonial arc radius in either group.

5. Although gonial arc radius was not clearly related to relapse, there was a disturbingly high incidence of condylar distraction. The design of a simple but effective condylar locating devices should be pursued. The method of establishing centric relation described by Raveh et al., (1988) should be evaluated further.

6. The early postoperative phase remains a critical period in evaluating surgical relapse. Relapse of -20.3% and -13.6% was recorded for the screw and wire fixation groups respectively and accounted for more than half of the overall relapse after one year.

7. The rate of relapse for the screw fixation group was much higher than the reported relapse rates for this method. Relative surgical inexperience with the technique may have accounted for some of this effect. Prospective studies which compare the results of consultant and trainee staff may confirm whether experience is a major consideration.

8. This study confirmed the findings of previously published research that mandibular relapse continued into the intermediate period. The data from this study showed a mean percentage relapse of -32% in the first 12 months.

9. Relapse was not appreciably different between the fixation groups in the intermediate or long term. The screw fixation group averaged -37.0% relapse at 12 months and the wire fixation group relapsed a mean -27.1%. Clinical decisions regarding the amount of mandibular advancement and the method of fixation should be based on the expectation that some relapse will occur in the early and intermediate phase.

10. Although this study did not show screw fixation to be superior to wire osteosynthesis, the current literature indicates that relapse tendency is less with screw fixation. This form of fixation requires continued critical investigation to determine its usefulness.

11. In common with the conclusions of Lake et al. (1981), Smith et al. (1985) and Van Sickels and Flanary (1985), intermediate relapse appeared to be correlated with the amount of surgical advancement in the mandible. This association was slightly stronger in the wire fixation group compared to the screw fixation group. Although part of the correlation was "specious", it was probable that a biological effect existed between the magnitude of advancement and mandibular relapse.

12. No single factor, with the possible exception of magnitude of advancement, was consistently responsible for relapse. The commonly discussed factors such as preoperative mandibular plane angle and altered gonial arc radius did not appear to influence the amount of relapse when the total sample was assessed as a single group. Correlation values for mandibular plane angle and relapse per cent were low for all intervals. No correlation with gonial arc radius and intermediate or long term relapse was shown by the sample.

13. There was a trend towards less relapse for bimaxillary cases but this was not statistically significant. High mandibular plane angle cases tended to have more relapse than low angle cases but none of these differences were statistically significant. In this study, the groups were too small for valid comparison and each differed in the magnitude of advancement. Larger surgical samples may show that bimaxillary procedures add to postoperative stability.

14. The age of the male patient at operation appeared to affect the intermediate relapse tendency. The teenage male subjects tended to relapse less than females and appeared to be unrelated to any of the cephalometric variables studied. It is postulated that this dimorphic effect may be related to the different maturation characteristics between males and females. The average age for females in this study was 19.8 years compared to 18.1 years for males. Whilst the female patients would have been skeletally mature, some growth potential would still be anticipated for the male group (Graber, 1969). However, to verify whether a true relationship exists, increased male sampling is required and skeletal age should be correlated rather than chronological age.

16. This investigation has shown that relapse is a complex issue. Several factors may contribute to mandibular relapse following bilateral sagittal split advancement. The resistance from paramandibular soft tissues (Epker and Wessberg, 1982) is the most logical, recognised relapse factor. Condylar distraction and the resistance of the soft tissue give logic to the concept of relapse but the wide variation in individual relapse patterns clearly shows that other factors are active.

17. The refinement and extension of this cephalometric investigation provides several avenues for further research:

    17.1. Prospective relapse studies which compare screw and wire fixation based on larger samples.
    17.2. Prospective studies which compare different screw diameters and configurations in relation to relapse.
    17.3. Prospective studies to establish the degree of association between skeletal age and relapse tendency.
    17.4. Prospective studies using the tantalum marker method of Wade (1988) to verify his finding that measurable relapse does not occur at the osteotomy site.
    17.5. Evaluate whether occlusion enhances stability by performing mandibular advancement in an edentulous animal model and comparing the findings with advancement in fully dentate animals.
    17.6. Evaluate paramandibular soft tissue influences. This is a difficult area to investigate but it could primarily use an animal model to:
        17.6.1. examine the effects of extensive buccal stripping of the soft tissue from the mandible.
        17.6.2. establish whether total alveolar mandibular osteotomy has less relapse. In this procedure, the anterior bone cuts are above the level of the anterior attachments of the suprahyoid complex.
    17.7. Retrospective evaluation of soft tissue changes following bilateral sagittal split advancement.
    17.8. Investigation of the validity of surgical prediction ratios and computer-aided prediction tracings.
    17.9. Comparison of hard and soft tissue treatment responses to orthodontic therapy and orthognathic surgery using subjects matched by skeletal age, sex and dentoskeletal dysplasia.
    17.10. Investigate skeletal changes in other kinds of surgical procedures such as Le Fort I osteotomy, using a modification of the computerised cephalometric program.

# VII

# Appendix

# APPENDIX 1

# BILATERAL SAGITTAL SPLIT OSTEOTOMY*

### *1. INDICATIONS*

1. Advancement or retrusion of the mandible in the horizontal plane.
2. Unilaterally for mandibular asymmetry. Sagittal split osteotomy on advancement side and vertical subsigmoid on retrusion side.

### *2. CONTRAINDICATIONS*

1. Vertical rotational movements of the mandible greater than 5 degrees as in anterior open bite cases.

### *3. PREOPERATIVE PROCEDURE*

#### 3.1. *Before Admission:*

1. Full orthognathic work up.
2. Third molars preferably removed six months prior to osteotomy.
3. Confirm means of intermaxillary fixation:
   a) arch bars
   b) orthodontic bands on 1st molars, premolars and canines and high hat pins.

#### 3.2. *On admission*

1. Full presurgical work up depending on age.
2. Check accuracy of the occlusal wafer.
3. Notify theatre - osteotomy instrument requirements.
4. Notify higher dependency ward.

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* Operation protocol from the Oral and Maxillofacial Surgery Unit, The University of Adelaide (Revised 1986, 1988).

## 4. OPERATIVE PROCEDURE

### 4.1. *Preparation*

1. Naso endotracheal intubation.
2. Intravenous dexamethasone 8 milligrams and cephalothin 1 gram.
3. Nasogastric tube.
4. 1% Cortef ointment to lips.
5. Position two wire cheek retractors and tongue retractor.
6. Inject 4 ml of 2% lignocaine with 1 in 80,000 adrenaline. Inject lateral to ascending ramus along external oblique ridge and latero-inferiorly near molars. Inject unilaterally if operator takes more than 30 minutes for osteotomy.

### 4.2. *Incision*

1. A 2 cm incision is made well buccal from a quarter way up the ascending ramus, along the external oblique ridge to the second molar. Buccal placement of the incision facilitates closure, whilst conservative superior extension avoids buccal fat herniation.

### 4.3. *Mucoperiosteal reflection*

1. Commence lateral to the second or third molar region and elevate to the lower border.
2. Place long reverse Langenbeck retractor and remove cheek retractor.
3. Reflect anterior border of ascending ramus.
4. Using two periosteal elevators scrape the tendon of the temporalis muscle off the anterior aspect of the ascending ramus.
5. Check most inferior point of sigmoid notch with No. 6 plastic.
6. Place forked Langenbeck retractor high up on anterior aspect of ascending ramus to aid stabilisation of retractor and to act as a reference point. Cut a slot in the ascending ramus at the level of the sigmoid notch using a small round bur then seat retractor in this slot.

7. Reflect mucoperiosteum from medial aspect of ascending ramus using a small periosteal elevator. Commence superiorly, working inferiorly and posteriorly until traction of the inferior alveolar neurovascular bundle is felt.
8. Visualise the lingula and neurovascular bundle.
9. Reflect mucoperiosteum superiorly and immediately posteriorly to the lingula.

### 4.4. *Placement of retractors*

1. Place channel retractor on medial aspect of ramus superiorly to lingula. The channel faces superiorly and is manipulated until it lies 3-5 mm posterior to the lingula.
2. Rotate 90 degrees so the channel faces laterally. The medial aspect of ramus should be well visualised and the neurovascular bundle well protected. Bend retractor handle as necessary.
2. Place channel retractor on lateral aspect of body of the mandible with the channel facing either anteriorly or posteriorly and insert to the level of the lower border. Rotate 90 degrees so the channel faces medially and engages the lower border of mandible.
3. Remove reverse Langenbeck retractor then bend the retractor handle as necessary.

### 4.5. *Osteotomies*

#### 4.5.1. Vertical lateral osteotomy

1. Usually lateral to first and second molar contact but for advancement of greater than 12 mm, lateral to distal contact of second premolar.
2. Keep channel retractor firmly against lower border.
3. Use a long Lindeman bur to cut through buccal cortex and inferior border of mandible.
4. As the alveolar bone is approached, curve the bone cut posteriorly above the external oblique ridge.

### 4.5.2. Horizontal medial osteotomy

1. At a level 5 mm below the sigmoid notch and above lingula.
2. Angulation of cut bisects the angle between the maxillary and mandibular planes.
3. Length of cut is 2 cm from anterior border.
4. Using a long Lindeman bur commence anteriorly and proceed posteriorly.
5. Anteriorly, the cut is made almost to the buccal cortex but further posteriorly it becomes more shallow.

### 4.5.3. Connecting vertical and horizontal osteotomies

1. Use a small round bur to drill multiple guide holes just medial to the buccal plate. These holes should pass through cortex to bleeding bone with long axis parallel to buccal cortex.
2. A medium Lindeman bur connects guide holes, firstly as a channel, then through cortex.
3. Being directly adjacent and parallel to the lateral cortex ensures that the neurovascular bundle is avoided and is in the distal fragment.

### 4.6. *Mobilisation of bone segments*

1. Insert one splitting osteotome at the posterior end of the connecting osteotomy parallel to buccal cortex.
2. Drive in 1 cm with a short sharp tap with the mallet and leave in place.
3. Insert one splitting osteotome at the anterior end of the connecting osteotomy parallel to buccal cortex.
4. Drive in 1 cm with a short sharp tap with the mallet and leave in place.
5. Twist both splitting osteotomes so that the connecting osteotomy opens. Suction gently and visualise nerve. Leave osteotomes in place.
6. Insert a 6 mm osteotome close to the anterior splitting osteotomes. Keep close to the buccal plate and ensure the nerve is visualised to the medial.
7. Tap the osteotome through to the lower border opposite the channel retractor.

8. If necessary, dissect the neurovascular bundle from the buccal cortex with a small periosteal elevator or No.6 plastic.
9. Complete the split by twisting both splitting osteotomes whilst ensuring that the nerve is not crushed.
10. If split does not occur insert a small osteotome in the inferior aspect of the vertical buccal cut below the nerve. Tap with mallet, with the channel retractor protecting the soft tissues.
11. Check that mobilisation of fragments is complete.
12. The third molar is removed at this stage.
13. Place a moist gauze between the outer plate and soft tissue and commence other side. If the inferior alveolar artery is damaged, pack 2 gauze packs between the fragments.

### *4.7. Fixation*

#### 4.7.1. Upper border wire osteosynthesis

1. Remove throat pack and suction out pharynx.
2. Insert wafer and check occlusion.
3. Place four 26 gauge intermaxillary wire loops.
4. To ensure condyles are properly seated in the glenoid fossa, use a gauze packer to apply pressure. Push the proximal segment downwards, then backwards and upwards.
5. Major advancements may need bone removal at the posterior superior aspect of the distal segment to prevent impingement on the maxillary teeth.
6. Place retractors: channel retractor on the buccal aspect.
   forked Langenbeck on the anterior border of the ascending ramus.
7. With a small periosteal elevator reflect the mucoperiosteum on the lingual aspect of the mandible.
8. With a hand drill pierce the cheek from the skin surface. Drill through the proximal fragment at right angles to the buccal cortex. Keep rotating the hand drill whilst changing the angulation to backward and upward and drill through the distal segment.
9. Pass a 26 gauge wire through the eye of the drill and place a small clip on the other end of the wire. Withdraw drill with wire from both the proximal and distal fragments. Remove wire from drill.

10. Check alignment of the proximal and distal fragments at the lower border.
11. Tighten osteosynthesis using the gauze packer to stabilise the proximal segment against the distal segment.
12. Repeat osteosynthesis on other side.
13. Close soft tissue with 3/0 Vicryl® suture.

4.7.2. Fixation with bicortical screws.

1. Remove throat pack and suction pharynx.
2. Insert wafer and check occlusion.
3. Place four 26 gauge intermaxillary wire loops.
4. The patient's head is placed facing straight upwards and the elasticity of the skin over the mandibular angles is determined. A 5 mm skin incision is made with a scalpel below the lower border of the mandible parallel to the resting skin tension lines.
5. A straight haemostat is advanced through the wound entering the intraoral site above the upper margin of the periosteum. The haemostat is replaced with the Wurzburg transbuccal trocar. By perforating soft tissue above the periosteum the trocar can be moved in any direction with minimal tissue resistance. The Wurzburg cheek retractor is attached to the handle and the trocar tip is removed. The retractor should rest against the lateral cortex of the proximal segment and be angled to allow maximum intraoral visibility.
6. A forked Langenbeck retractor is held firmly against the ascending ramus to assist seating the condylar head. The proximal segment is manipulated with a gauze packer so that the lower border is aligned and the condyle seated in the fossa. The gauze packer seats the condyle by a down, back and upward movement. This is a critical step in sagittal split osteotomies.
7. The trocar tip is placed against bone, directed towards the lingual cortex, distal to the teeth and angled away from the neurovascular bundle. The drill guide is inserted into the trocar.
8. Drilling is done at low speed using a 1.5 mm drillbit in an AO-Synthes trauma driver with copious saline irrigation.
9. The drill guide is removed and a 2 mm self tapping screw is pushed into the trocar. Screw length has to be estimated as it is not possible to

use a depth gauge with the trocar. The screw is tightened with the normal screwdriver.

10. Steps 7 to 9 are repeated twice so that a total of three screws is used per side. The usual placement is with 2 screws above the neurovascular bundle and one below. An inverted tripod arrangement may also be used if there is insufficient bone superiorly.
11. The procedure is repeated on the contralateral side.
12. The intermaxillary fixation is released and the occlusion checked carefully. If the teeth fail to occlude into the wafer, check for ramping. This can be confirmed by removing the wafer and comparing the occlusion to the model surgery. If present, grind the lingual surfaces of the wafer in the lower incisal region. If there is no evidence of ramping but a clear anterior-posterior discrepancy then the screws must be removed and reapplied. Screw fixation rarely allows for any compromise in occlusion.
13. Irrigate the wounds and close intraorally wound with 3/0 interrupted resorbable sutures. Dermalon® 5/0 suture is used to close skin.
14. Combine pads are placed over buccal tissues and held by a 6 cm crepe bandage to provide a pressure dressing.

## *5. POSTOPERATIVE MANAGEMENT*

### 5.1. *Immediate*

1. High dependency recovery for first 24 hours.
2. Intravenous dexamethasone 8 milligrams 12 hourly and cephalothin 1 gram 6 hourly are continued for 48 hours.
3. Narcotic analgesia eg. papaveretum 10 milligrams IM 4 hourly prn is gradually replaced with paracetamol-codeine combinations.
4. Clear fluids are given in the first 24 hours then upgraded.

### 5.2. *Post operative recovery:*

1. Oral intake and ambulation are encouraged.
2. Postoperative lateral head cephalogram, PA mandible and OPG are taken as early as possible to confirm the accuracy of surgery.

# VIII

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