

D9DC  
A865  
102



## **3D LASER SCANNING OF DENTAL IMPRESSIONS**

Volume 1.

*Purpose:*

A Thesis Submitted in Partial Fulfilment for the Degree of  
Doctorate in Clinical Dentistry.

*By:*

Matthew Athanassiadis

*Institution:*

Dental School  
Faculty of Health Science  
University of Adelaide

*Date:*

26/09/2006

*Stage of Thesis:*

Final Copy

# Table of Contents

## Volume 1

3D LASER SCANNING OF DENTAL IMPRESSIONS .....	1
Table of Contents .....	2
List of Figures .....	5
List of Tables .....	7
Statement of Declaration .....	8
Abstract .....	9
<b>1. Aims .....</b>	<b>12</b>
Literature Review .....	14
1.1. Purpose of Research .....	14
1.2. Types of Scanning Methods .....	17
a) Cephalometric Radiography .....	18
b) CT Scanning .....	19
c) Direct Intraoral Imaging .....	19
d) Stereophotogrammetry .....	22
e) Structured Light .....	25
f) Ultrasonic Digitizing .....	27
g) Co-ordinate Measuring Machines .....	29
h) Combinations .....	32
i) Moire Contourography .....	32
1.3. General 3D Concepts .....	33
1.4. Types of Images and Common Terminology .....	36
1.5. Principles of Rapid Prototyping .....	39
a) Incremental .....	39
b) Hybrid (Incremental and Decremental) .....	46
c) Decremental .....	47
c) Non-Cutting Deformation-Based Technologies .....	48
1.6. Commercially available systems .....	49
a) E Model .....	49
b) Invisalign .....	50
c) Suresmile .....	51
1.7. Direction of Proposed Research. ....	53
<b>2. Methods and Materials.....</b>	<b>56</b>
2.1. Proposal for Combined Scans of Half-impressions .....	56
2.2. Choice of Sample .....	57
a. Selection Criteria .....	57
b. Sample Size .....	57
c. Ordering of the Sample for Measuring .....	57
2.3. Procedure for Impressions and Scanning .....	58
a. Preparation of Impressions for Laser Scanning .....	58
b. Preparation of Impressions for CT Scanning .....	59
c. Laser Scanning of Plaster Models .....	59
2.4. Scanners .....	59
a. Roland LPX1200 .....	59
b. Model Maker Z35 Scanner .....	60

2.5.	Measuring Instruments.....	61
a.	Vernier Calipers .....	61
b.	Software .....	62
2.6.	Measures Taken .....	62
2.7.	Image Manipulation.....	63
a.	Scanned Half-impressions .....	63
b.	Scans of the Plaster Models.....	64
c.	Measurements on the Physical Plaster Models.....	64
d.	CT scans of Full Impressions of the Models .....	64
2.8.	Statistical Analysis and Proposed Structure.....	65
a.	Proposed Structure .....	65
b.	Actual Structure.....	65
c.	Statistical Software.....	68
2.9.	Analysis of Errors in the Study .....	70
<b>3.</b>	<b>Results .....</b>	<b>73</b>
3.1.	Technique .....	73
a.	Scanner Choice.....	73
b.	Statistical Shortcomings in the Method .....	75
c.	Manipulation of Images .....	75
3.2.	Measures .....	77
a.	Quickly Measured Distances - Appendix H for full set of results. ....	77
b.	Precisely Measured Distances – Appendix G for full set of results. ....	77
3.3.	Tests for Normality .....	78
a.	Quickly Measured Distances – Appendix H for full set of results .....	78
b.	Precisely Measured Distances – Appendix G for full set of results .....	78
c.	Summary.....	79
3.4.	Repeated Measures Anova and Friedman Rank Test .....	81
a.	Quickly Measured Distances – Appendix H for full set of results .....	81
b.	Precisely Measured Distances – Appendix G for full set of results .....	81
c.	Summary.....	81
d.	Measures Indicating a Significant Difference Between Groups at a Level of $p < 0.05$ .....	83
e.	Summary of Results .....	86
3.5.	Error Analysis.....	87
a.	Quickly Measured Distances – Appendix H for full set of results .....	87
b.	Precisely Measured Distances – Appendix G for full set of results .....	87
c.	Summary.....	88
<b>4.</b>	<b>Discussion .....</b>	<b>95</b>
<b>5.</b>	<b>Conclusions.....</b>	<b>103</b>
<b>6.</b>	<b>Directions for Future Research.....</b>	<b>104</b>
<b>7.</b>	<b>Acknowledgements.....</b>	<b>105</b>

**Volume 2**

<b>Appendix A Reference Models</b> .....	<b>108</b>
<b>Appendix B Lower Impression Trays</b> .....	<b>114</b>
<b>Appendix C Materials</b> .....	<b>115</b>
<b>Appendix D Scanner Information</b> .....	<b>116</b>
<b>Appendix E Software</b> .....	<b>122</b>
<b>Appendix G Complete List of Results – Precisely Measured Distances ...</b>	<b>148</b>
Averaged Measures.....	148
Test of Normal Distribution for Precisely Measured Distances .....	153
Repeated Measures ANOVA and Friedman-Test on the Precisely Measured Distances.....	158
T-Tests and Error Analysis on Precisely Measured Distances .....	166
<b>Appendix H – Complete Set of Results – Quickly Measured Distances ....</b>	<b>198</b>
Averaged Measures.....	198
Test of Normal Distribution for Quickly Measured Distances.....	203
Repeated Measures ANOVA and Friedman Rank Test on Quickly Measured Distances .....	208
T-Tests and Error Analysis on Quickly Measured Distances .....	215
<b>Appendix I Pictorial Representation of Laser Scanning Procedure</b> .....	<b>247</b>
<b>Appendix J Example of an ASC File</b> .....	<b>255</b>
<b>Appendix K Examples of Roland LPX1200 scans.</b> .....	<b>256</b>
<b>Bibliography</b> .....	<b>258</b>
<b>Presentation CD</b> .....	<b>260</b>

## **Abstract**

The 3D laser scanning of dental impressions has always been considered difficult if not impossible to do. The problem arises from the inability of the laser scanner to scan the deeper portions of an impression which are often also undercut. This has always been a known limitation of laser scanning. The review of literature confirmed this as there was very little written on the laser scanning of dental impressions.

In this research project, a philosophy was adopted whereby an insurmountable problem was transferred to one which was not – a common technique used in mathematics to solve difficult problems. To this end, a new technique was developed. In order to successfully scan the deep indents formed by the dentition, half-impressions were taken. These half-impressions were of the lingual occlusal and buccal occlusal surfaces. This, by simple design, resulted in the elimination of the undercuts allowing the laser scanner to scan the areas which were previously considered difficult or impossible. The problem then became one of inverting the scans and combining them to form a complete 3D virtual image of the dental arch. The occlusal surface was used as the area of commonality and each half-scan was inverted and aligned to form the full virtual image of the dental arch.

Once the technique was developed, the scans were compared against other known methods for generating virtual models as well as against the plaster reference models.

There were five pairs of plaster models used, each with an increasing amount of crowding. Half-impressions were taken of the models and laser-scanned. This resulted in ten sets of virtual models derived from the scans of the half-impressions.

The four groups compared were as follows:

1. Plaster Models with measures taken with vernier callipers and dividers.
2. Laser-scanned plaster models with measures taken using computer software.
3. Combined laser-scans of the half-impressions with measures taken using specific orthodontic software for virtual models.
4. CT-scanned full impressions with measures taken using proprietary software provided by the scanner manufacturer.

The measures used to compare the four groups were individual tooth sizes and arch widths. For this research project, the statement was made – *“There is no gold standard for measuring the size of teeth to the standard required for study models”*. The aim of the statistical design was to compare the four methods as a whole and to show that there was no significant difference between any method when compared against the others, i.e. that all methods were essentially equivalent. This was achieved by using a Repeated Measures ANOVA to compare the four groups of measures.

The measuring of the models was performed in two distinct ways. Firstly, all models were measured quickly to simulate how they would be measured in a clinic. The same groups were then measured precisely with the measures being

taken in a way which provided the best possible chance of measuring identical points on the same model across the different groups.

The results indicated no significant difference between the four methods whether they were measured quickly or precisely. The scanning and combining of the half-impressions to form a complete virtual image is considered a valid method for producing virtual images of a dental arch.

Future research could concentrate on refining the technique, hardware and software required.



# 3D LASER SCANNING OF DENTAL IMPRESSIONS

Volume 2.

*Purpose:*

A Thesis Submitted in Partial Fulfilment for the Degree of  
Doctorate in Clinical Dentistry.

By:

Matthew Athanassiadis

Institution:

Dental School  
Faculty of Health Science  
University of Adelaide

*Date:*

26/09/2006

*Stage of Thesis:*

Examiners' Copy