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Accuracy of Ortho Insight 3D Digital Scanner in Mesial-Distal Tooth Measurements

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Accuracy of Ortho Insight 3D Digital Scanner in Mesial-Distal Tooth Measurements

by

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A Thesis submitted in partial satisfaction of
the requirements for the degree of
Master of Science in Orthodontics and Dentofacial Orthopedics

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Each person whose signature appears below certifies that this thesis in his/her opinion is adequate, in scope and quality as a thesis for the degree of Master of Science.

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ABBREVIATIONS

ABO	American Board of Orthodontics
2D	Two-dimensional
3D	Three-dimensional
CBCT	Cone-beam Computed Tomography
ICC	Intra-class correlation coefficient
MD	Mesial-Distal
mm	Millimeter
Mod	Modality
OGS	Objective grading system
SD	Standard Deviation
HATS	Hamilton Arch Tooth System

ABSTRACT OF THE THESIS

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Tooth Measurements

By

Andrew A. Ferris

Master of Science, Graduate Program in Orthodontics and Dentofacial Orthopedics
School of Dentistry, August 2012
V. Leroy Leggitt, Chairperson

Introduction: Digital scanners and software may be used to measure mesial-distal (MD) tooth width for orthodontic diagnosis and treatment planning. Although there have been many studies performed on different digital scanners, accuracy of mesial-distal tooth measurements using the Ortho Insight 3D scanner and its software (Motionview Software LLC) has not been reported.

Purpose: The objective of this study was to determine if the MD tooth measurements from the digital models scanned by Ortho Insight 3D are accurate compared to the measurements taken directly from the teeth and models with a digital caliper.

Material and Methods: Individual MD tooth measurements were taken with a digital caliper on maxillary and mandibular plastic teeth. These teeth were then set in wax, with varying degrees of crowding and scanned with the Ortho Insight 3D. The corresponding digital models were measured with the software. Impressions were then taken of the set ups, scanned and poured in dental stone. The resulting digital models from the scanned impressions and casts were measured. The dental stone models were also measured with a caliper. In total, three digital models were created for each of the set ups and a comparison was made between the individual, software, and cast measurements of teeth to determine the accuracy of the Ortho Insight 3D measurements.

Statistical Analysis: An Intraclass correlation coefficient (ICC) was used to compare resulting MD measurements from the different digital models to the caliper measurements to determine agreement. The model teeth, digital models, and casts were re-measured for reliability using Cronbach's Alpha. Bland-Altman plots were used to visualize the results and illustrate whether or not the resulting measurements of Ortho Insight 3D were statistically and clinically accurate.

Results: Measurements made from the Ortho Insight 3D showed a statistically and clinically significant correlation and agreement with reference measurements, accurate within two standard deviations per arch. Findings indicated that traditional measurements using calipers on stone models and digital measurements on scanned stone models were more accurate than digital measurements on scanned impressions.

Conclusions: The accuracy of MD tooth widths measured with the Ortho Insight 3D scanner are clinically acceptable and can aid in orthodontic clinical diagnosis and treatment planning.

CHAPTER ONE

INTRODUCTION

Statement of the Problem

With the advancement in diagnostic software over the past decades, Orthodontics, like many other fields, is transitioning to digital. The ability to store patient information, pictures, and X-rays digitally is very attractive because it saves space, time, and money. One area that is continuing to advance is the use of digital models. Digital models, if determined to be as accurate as physical casts, will be extremely beneficial. In order to achieve quality orthodontic results, comprehensive diagnosis and treatment planning must first take place. The discrepancy between the amount of arch length available and the summation of the tooth sizes is critical in determining the treatment options. Traditionally, orthodontists measure the tooth width with calipers on the stone models.

As technology has advanced, orthodontic offices are becoming digitized in all aspects, i.e. charting, models, etc. In order to use digital models to treatment plan, the accuracy and reproducibility need to be evaluated if the clinician is going to trust them in determining treatment options. In the past few years, several companies have entered the market with 3D scanners that allow an orthodontist to send an impression to a third party which scans and produces a digital model that is sent back to the orthodontist via the internet in digital format. The orthodontist can then use software to evaluate, manipulate, and measure the models. The problem is that the turn around from the time the impression is taken until the orthodontist receives the digital form is usually at least ten days, an obvious disadvantage compared to analog models.

Recently, Motion View Software developed an in-house system for scanning of impressions and models specifically for the orthodontist. This laser scanner, called Ortho Insight 3D, and its software allows the orthodontist to scan the impression and turn it into a 3D viewable model, in occlusion, in a matter of minutes. Quick pours and stored models can also be easily transferred to digital images, therefore reducing the need to store plaster models.

The Ortho Insight 3D software includes features such as measurements, Bolton Analysis, occlusal evaluation, and object segmentation, which allows the orthodontist to fabricate diagnostic virtual wax ups. To this point, there have been no known studies that look at accuracy of the Ortho Insight 3D, specifically looking at mesial-distal tooth width.

Hypothesis

The null hypothesis in this study was: There is no significant correlation and agreement between the measurements of MD tooth widths produced by the Ortho Insight 3D and the corresponding measurements using a caliper on the individual teeth.

The alternative hypothesis was: There is significant correlation and agreement between the measurements of MD tooth widths produced by the Ortho Insight 3D and the corresponding measurements using a caliper on the individual teeth.

CHAPTER TWO

REVIEW OF THE LITERATURE

Measurement of Traditional Casts

In order to compare the accuracy of digital models, it is important to first examine the techniques to evaluate traditional models and ascertain accuracy and consistency to create a solid foundation to perform comparison studies. Many studies reference a paper by Hunter and Priest[1] as a source for information regarding how to measure models. The authors describe the process as lining up the beaks of calipers along the long axis of the tooth to be measured. This study also points out measurements of certain teeth such as maxillary molars, lateral incisors, and mandibular incisors are difficult to measure due to tooth morphology.

In order to perform a valuable study where measurements are collected, bias must be avoided. Randomization of record measurement is one of the most important methods of avoiding bias[2]. Replication of measurements can be important in the control of random errors. In many studies, adequate error evaluation and control is lacking, which causes the results to be of limited value because it is not possible to tell whether an effect is the result of bias in measurement or whether a real effect is being obscured by random errors.

Rossouw[3] performed a valuable study of measurements on traditional casts using three different methods in measuring dental models: Vernier caliper, reflex metrograph, and reflection holograms. In his study, he found no significant difference between measurements made by the various techniques. This is valuable in this study because a digital caliper was used to measure models and was proven to be accurate.

Accuracy of Digital Measurements

Before the development of computer-aided design technologies to create digital models, other approaches were taken to digitize models such as holograms, photocopies, photos, etc,[4-8] however, these approaches all had their limitations. When comparing plaster models to photocopies of the same models, the MD tooth measurements were taken using calipers on the models and a digitizer for the photocopies. It was determined that the computer-aided measuring system was reliable but was not accurate for the measurements of MD tooth widths. Manual measurements were determined superior.

With advancements in lasers, they began to be used in scanning and creating digital models. Kurdora[9] introduced an article testing a dental cast analyzing system with laser scanning. He demonstrated the measurement error to be less than 0.5mm and was able to calculate the volume of the oral cavity. It was determined that this technology could be useful for surgery replacing the need for mock surgeries in treatment planning. Another study[10] pertained to using ultrahigh-speed laser scanners to reproduce dentition and occlusion. The resulting data was satisfactory for the flat surfaces but less accurate for the inclined surfaces. The occlusion was able to be viewed from multiple angles digitally which the author postulated could be used for diagnosis and treatment planning and replacement of stone casts. The problem with the study was that the accuracy was not evaluated sufficiently.

Another study by Keating[11] was performed to evaluate accuracy and reproducibility of a three-dimensional optical scanning laser device to evaluate surface detail compared to plaster models. A Minolta Vivid 900 non-contact surface laser was used in the study. This study was different than others because it not only evaluated plaster models and 3D surface models, but also physical replicas created using a rapid prototyping manufacturing process. These replicas would be valuable for the clinician that wants a digital model and a recreated physical model from that digital model. In this article, it was determined that the measurements made on the digital models and plaster models had a mean difference of .014mm, which was not statistically significant. It was determined that in the replica models created from the scan, there were significant differences, therefore, appropriate detail and accuracy cannot be reproduced from scanned data using this reconstruction technique.

Several variables exist that play a role in evaluating if digital models are as accurate as plaster models; the impression material is one such factor. A study[12] compared the dimensional stability of four impression materials over time to compare OraMetrix digital models versus traditional plaster models. Two were traditional alginates and two were alginate substitutes. The plaster models were poured at different time periods and the impressions for digital models were sent to a company at 72 hours. The models were measured for anterior-posterior, transverse, and vertical dimensions. Digital models were significantly smaller in all dimensions compared with plaster models and the control. It was determined that the alginate was more accurate when poured immediately, and alginate substitutes were stable over an extended period. Digital models produced by OraMetrix were not clinically acceptable compared with plaster models. Our study used polyvinylsiloxane impression material, which was proven most accurate and stable.

There are several companies that generate digital models for the orthodontist.[13-14] The company with the largest market share in this field, and a competitor of Ortho Insight 3D, is OrthoCAD by Cadent Inc. This company has made the biggest strides in developing a practical way for orthodontists to obtain digital models from the impressions taken in their clinics. Several articles[15,16] describe in detail OrthoCAD technology. The process of sending impressions and receiving the digital models is outlined. Space storage is a concern, and with digital models, 6000 can be stored on one 20GB hard drive. A virtual on-screen caliper allows midline, overbite-overjet, and arch length discrepancy measurement to be performed. OrthoCAD technology has the ability to revolutionize the way study models are used, stored, viewed and managed. The models can be brought up instantly, rotated, viewed and held in that position from every angle.

Since the literature predicts that these digital models created by OrthoCAD will be the future, it is important to evaluate this technology's accuracy and reliability. Two significant studies[17-19] were done using traditional plaster casts in comparison to OrthoCAD digital models to evaluate tooth size and arch width and to compare space analysis with the two methods. Zilberman[17] compared the use of calipers to measure plaster casts and OrthoCAD measurement systems to determine if there is a difference in accuracy. Twenty setups using artificial teeth corresponding to various malocclusions were created. Measurements of mesiodistal tooth width, intercanine distance, and intermolar distance were measured using both methods. The results indicated that measurement with digital calipers on plaster models showed the highest accuracy and reproducibility. OrthoCAD was determined to be clinically acceptable. Therefore, Zilberman believed the OrthoCAD process would become the standard for the future.

Leifert[17] conducted a study using plaster models and OrthoCAD to compared space analysis measurements. Two sets of 25 alginate impressions were taken on permanent Class I crowded dentition. Each was made into a plaster model and digital model. On the plaster models, tooth widths were measured using a digital caliper and arch length with a brass wire. The digital models were measured using the OrthoCAD dedicated software and Space analysis and crowding were assessed. The results indicate that there was a slight but statistically significant difference in space analysis on maxillary models between the digital and plaster models. It was determined that the overall the accuracy and reproducibility were clinically acceptable for digital models when comparing to plaster models.

Another study[19] to determine the accuracy, reproducibility, efficacy, and effectiveness of measurements made on computer-based models was performed. A plastic model occlusion served as a gold standard. Only measurements of space available made on computer-based models differed from the measurements made on the gold standard, reproducibility was high on both. Since all the elements except space available were similar with regards to plaster and digital models, computer-based models appear to be a clinically acceptable alternative to conventional plaster models.

The above studies encouraged newer companies, such as MotionView Software, to continue to make advancements in scanning technology.

American Board of Orthodontics

Ortho Insight 3D and its competitors may gain more acceptance among orthodontists if deemed accurate enough to be used for the ABO exam. In order to evaluate the ABO phase III examination, a fair and objective grading system was introduced. Seven criteria are examined: tooth alignment, vertical positioning of marginal ridges, buccolingual inclination of posterior teeth, occlusal relationship, occlusal contacts, overjet, and interproximal contacts. Three studies[20-22] have been performed to evaluate if digital models are accurate enough to be used for grading this exam.

Costalos's study[20] evaluated plaster and digital models of 24 patients post-treatment. The means of the total score and those for marginal ridges, occlusal contacts, occlusal relationships, overjet, and interproximal contacts were not statistically significant between plaster and digital models. However, the means for tooth alignment and buccolingual inclinations were statistically significantly different. This study indicates that although two measurements were significantly different, digital models may still be acceptable for ABO grading.

Hildebrand's article[21] evaluated the software program for applying the ABO grading system to digital casts. His study used 36 finished orthodontic cases in plaster and digital model forms. An electronic version of the ABO OGS was used with the digital casts and the ABO gauge used on the plaster casts. There was a statistically significant difference when comparing the digital to the manual scores. The digital scores exceeded the scores from the plaster casts, and the difference was due to statistical significant discrepancies in three areas: alignment, occlusal contact, overjet. As a result, the study determined that the computer grading cannot be a substitute for plaster models in ABO evaluation.

In a similar study by Okunami[22], he wanted to determine if there was a statistical difference between digital and plaster models in scoring the ABO OGS. Thirty post-treatment casts were used in this study. It showed a significant difference between the plaster and digital casts for occlusal contacts, occlusal relationship, and total scores. No significant difference was found for alignment, marginal ridges, overjet, and interproximal contacts; this study did not include buccolingual inclination in this study. The study concurred that the digital program was not adequate for scoring all parameters of the ABO exam.

Bolton Analysis

If the measurements involved in analyzing models digitally with Ortho Insight 3D prove to be as accurate as plaster models, it significantly increase efficiency of orthodontists. Performing a Bolton Analysis and waxing up different scenarios are very time-consuming activities for orthodontists. If the tooth dimensions are accurate digitally, then digital setups should be accurate, and the computer should be able to evaluate tooth size discrepancies accurately. Several studies[23-28] have focused on digital Bolton Analysis. Bolton's[23,24] research developed ratios to compare tooth size and determine tooth size discrepancy. One of the studies[25] looked at the accuracy and validity of space analysis using digital models. The tooth size - arch length discrepancies on 50 sets of pre-treatment plaster casts were analyzed. Manual calipers were used for measurement and then the casts were digitally scanned with OrthoCAD. The study concluded that reliable measurements of the irregularity index and the tooth arch length discrepancy can be made on digital models and determined that digital measurements were more consistent than on plaster models.

In another study, Tomassetti[26] compared three computerized Bolton tooth-size analyses with a commonly used method. Twenty-two models were used, half pre-treatment and half post-treatment. Calipers on plaster were compared to Hamiltion Arch Tooth System, OrthoCAD, and Quick Ceph. No significant error was found, but clinically significant differences were present for each method. The HATS was most near the control, followed by OrthoCAD and then Quick Ceph. The time it took for each on was also calculated. Advancements need to be made in accuracy in order to replace plaster models.

CHAPTER THREE

MATERIALS AND METHOD

A complete set of radiopaque plastic teeth (maxillary and mandibular second molar to second molar) [Orthodontic Design and Production Inc., Vista, California] was microabraded with Aluminum oxide 50 micron to reduce the surface shine. Every tooth was measured from mesial to distal contact point using a digital caliper (Cen-Tech ® 4-inch Digital Caliper Model 47256, Pittsburgh) [Figure 1]. For consistency in measuring the teeth, a method similar in fashion to that of Hunter and Priest [1] was utilized in which the MD tooth width was estimated with the points of calipers parallel to the long axis of the crown at normal contact areas.

Figure 1. Digital Caliper

The teeth were then set in base plate wax, and the following degrees of arch length discrepancy (ALD) were used. No crowding (≈0 mm; Figure 2), mild crowding (≈3 mm; Figure 3), moderate crowding (≈6mm; Figure 4), severe crowding (≈9 mm; Figure 5), and extremely severe crowding (≈12 mm; Figure 6).

Figure 2. Non Crowded Wax Model

Figure 3. Mildly Crowded Wax Model

Figure 4. Moderately Crowded Wax Model

Figure 5. Severely Crowded Wax Model

Figure 6. Extremely Severe Crowded Wax Model

These ten waxed arches (five maxillary and five mandibular) were scanned using the Ortho Insight 3D (Figure 7). The following prompted steps of the software were followed in order to digitally obtain a final MD measurement of each of the 14 teeth per arch (Figure 8):

1. Separate teeth. This highlights the tooth and allows the user to define the margins.
2. Detect landmarks. The software identifies the different anatomical structures of each tooth, such as the mesial and buccal cusps, marginal ridges, etc., that the user can modify.
3. Detect facial axes. This allows the user to define the facial axis of each tooth.
4. Measure teeth. This function of the software estimates the contact points on the mesial and distal tooth surface. The user can modify these points by magnifying each tooth individually and picking the best points to obtain a MD measurement.
5. Align roots with crowns. This function was not used in this study.
6. Mass analysis: The software creates a table with the size of each tooth mesial-distally and a Bolton analysis.

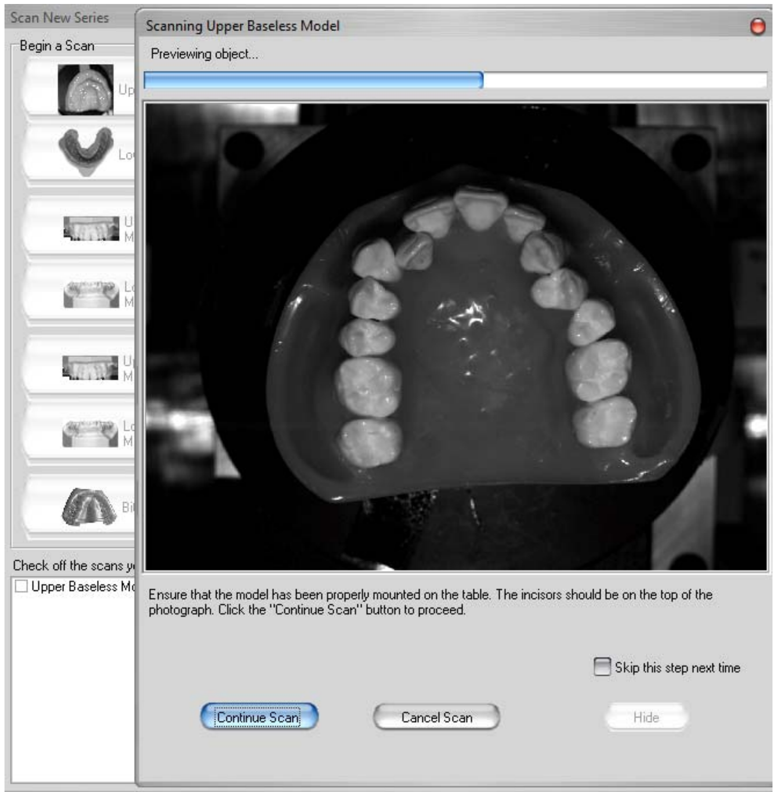

Figure 7. Preview of the Wax Model Scan

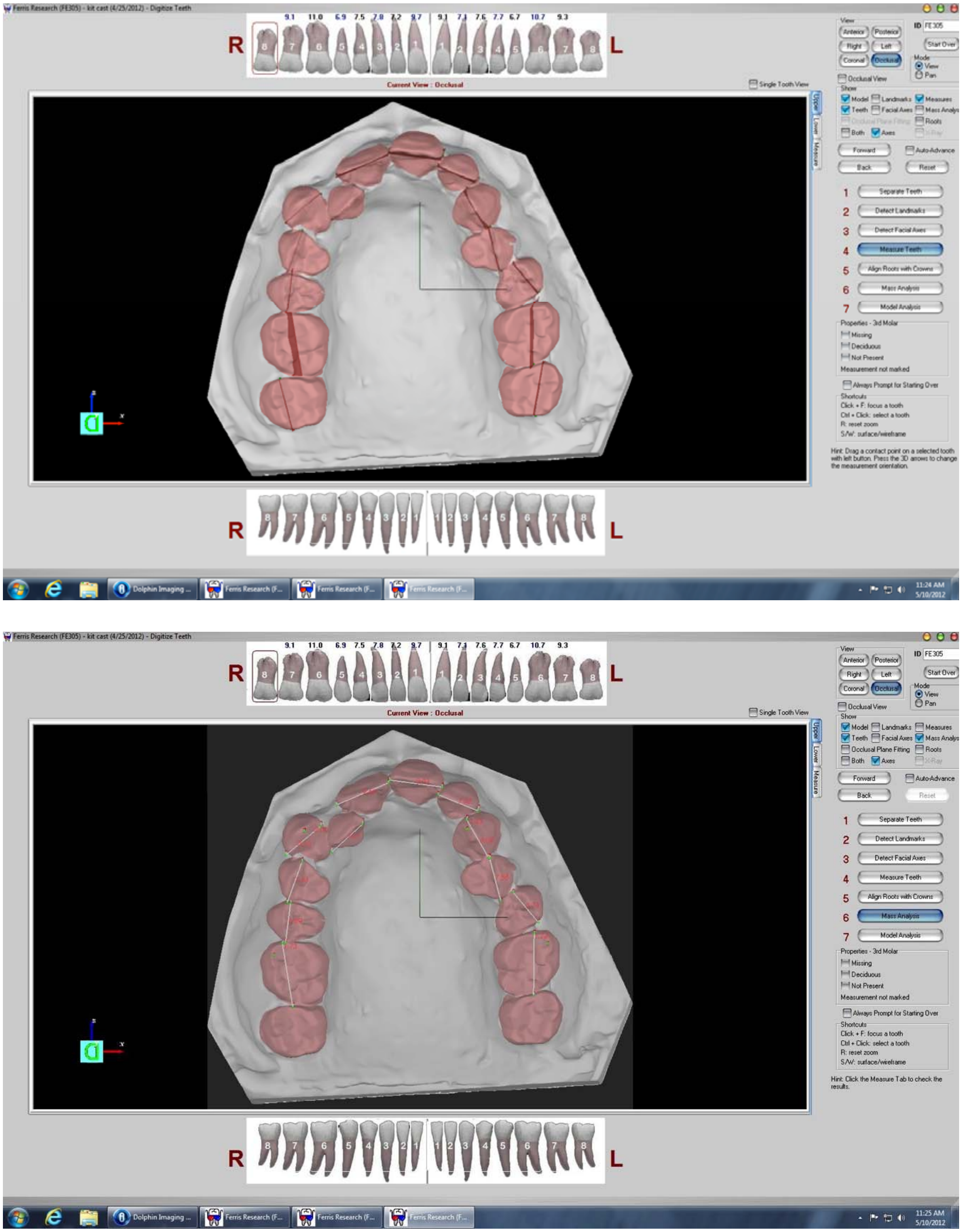

Figure 8. Digital Scan Software Measurement

Subsequently, an impression was taken of each wax model using Polyvinylsiloxane (Aquasil, Dentsply, York, PA [Figure 9]. The impressions were scanned and the resulting digital casts were also measured using the above protocol (Figure 10). After obtaining these measurements, the impressions were poured in dental stone (Figure 11). The stone models were scanned and digitally measured (Figure 12). Each tooth on all the final stone models was also directly manually measured using the digital caliper. The same digital caliper was then used to measure each tooth on all of these final casts. This last modality is conventionally how MD tooth width is measured.

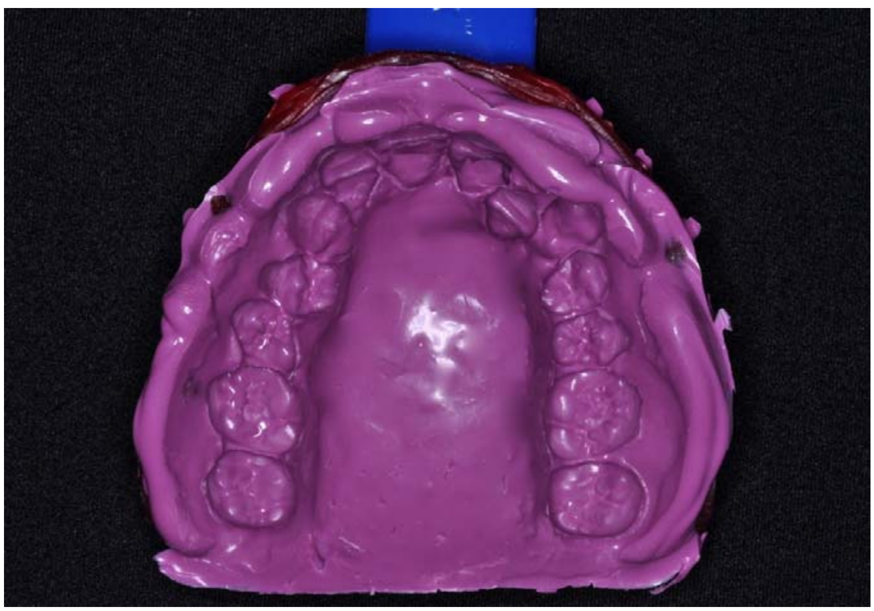

Figure 9. Polyvinylsiloxane Impression

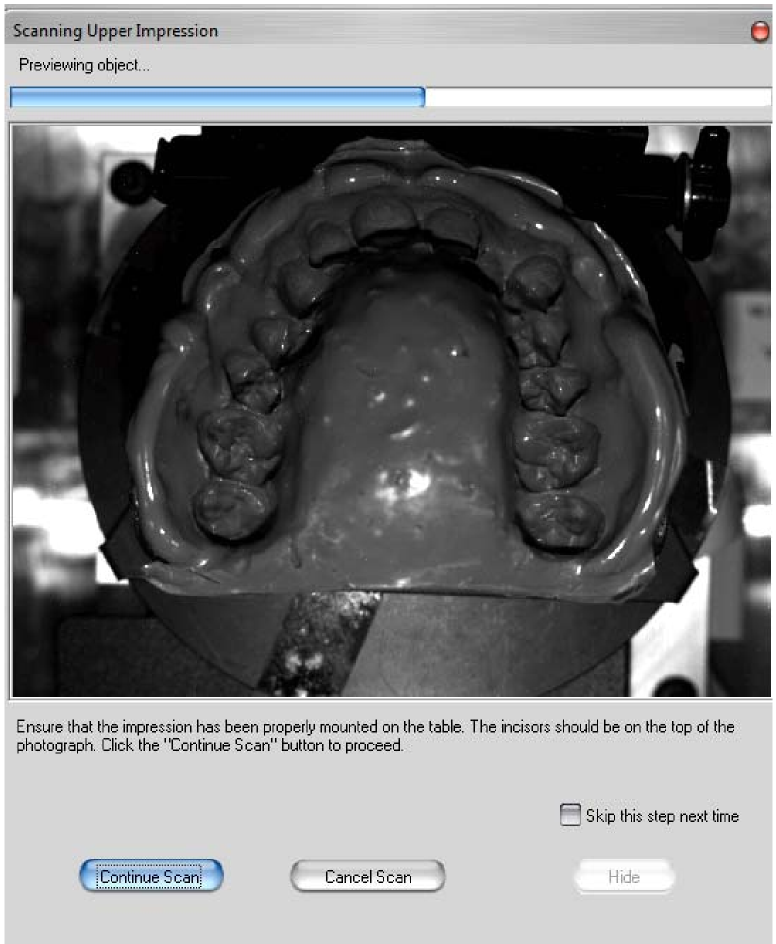

Figure 10. Preview of the Impression Scan

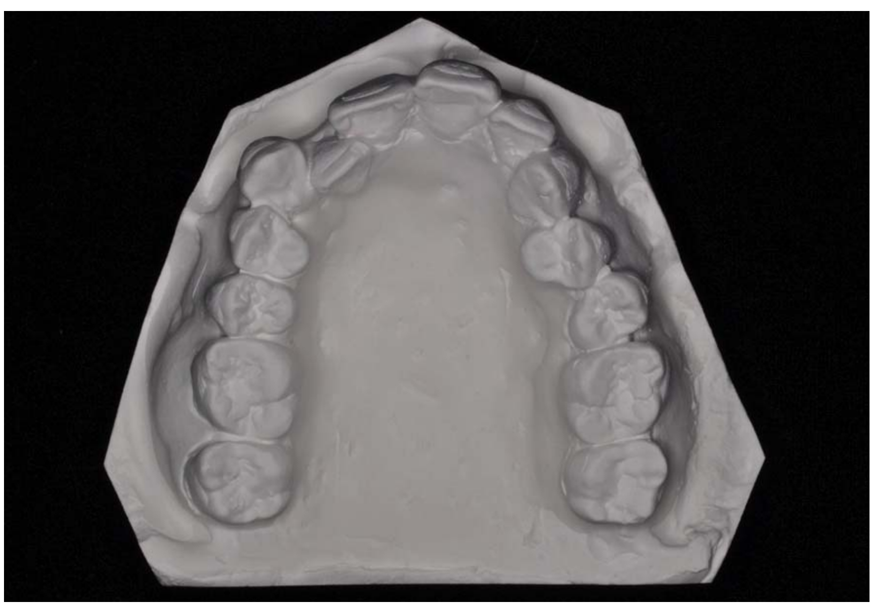

Figure 11. Cast of the Stone Model

Figure 12. Preview of Stone Model

In summary, the following five modalities of measurements were made for each degree of crowding:

1. Direct measurement of free standing individual teeth with digital calipers. This is considered the “Gold Standard.” (Mod 1).
2. Digital measurement of the teeth on the scanned wax model (Mod 2).
3. Digital measurement of the teeth on the scanned impression (Mod 3).
4. Digital measurement of the teeth on the scanned stone model (Mod 4).
5. Direct measurement of the teeth on the stone model or “Clinical Standard” (Mod 5).

Statistical Analysis

All measurements were repeated three times at different time points to evaluate measurement method reliability using Cronbach's alpha (SAS v.9.229, SPSS v. 1830). Intra class correlation coefficients (ICC) [SAS v.9.229, SPSS v. 1830] were used to express the correlation and agreement of each modality with the "Gold Standard". Bland Altman plots [R v. 2.10.131] were used to compare all the measurements to the "Gold Standard" to determine clinical significance within two standard deviations.

CHAPTER FOUR

RESULTS

Reliability

The high coefficients of Cronbach's alpha shown in Table 1 demonstrate high reliability of the measurement method used in this study.

Table 1. Reliability – Cronbach's Alpha

Measurement Method	*Cronbach's Alpha*
Direct Measurement on Individual Teeth	1.0
Digital Measurement on Scanned Wax Model	.997
Digital Measurement on Scanned Impression	. 994
Digital Measurement on Scanned Stone Model	.996
Direct on Measurement Stone Model	.997

Intraclass Correlation Test

The extremely high ICC values displayed on Table 2 show that all the modalities correlate and agree well with gold standard measurements at a statistically significant level regardless of the level of crowding.

Table 2. Intraclass Correlation Coefficients (ICC) of each measurement modality against the “Gold Standard”

Measurement Method	Mean Difference	95% Confidence Interval		F Test Sig
		Lower Bound	Upper Bound	
Mod 2 ALD ≈ 0	0.965	0.672	0.990	0.000
Mod 3 ALD ≈ 0	0.977	0.947	0.990	0.000
Mod 4 ALD ≈ 0	0.990	0.972	0.996	0.000
Mod 5 ALD ≈ 0	0.994	0.987	0.997	0.000
Mod 2 ALD ≈ 3	0.985	0.965	0.993	0.000
Mod 3 ALD ≈ 3	0.969	0.814	0.990	0.000
Mod 4 ALD ≈ 3	0.991	0.980	0.996	0.000
Mod 5 ALD ≈ 3	0.996	0.992	0.998	0.000
Mod 2 ALD ≈ 6	0.976	0.935	0.990	0.000
Mod 3 ALD ≈ 6	0.952	0.427	0.987	0.000
Mod 4 ALD ≈ 6	0.989	0.972	0.995	0.000
Mod 5 ALD ≈ 6	0.993	0.985	0.997	0.000
Mod 2 ALD ≈ 9	0.983	0.963	0.992	0.000
Mod 3 ALD ≈ 9	0.973	0.747	0.992	0.000
Mod 4 ALD ≈ 9	0.993	0.983	0.997	0.000
Mod 5 ALD ≈ 9	0.993	0.984	0.997	0.000
Mod 2 ALD ≈ 12	0.983	0.962	0.992	0.000
Mod 3 ALD ≈ 12	0.972	0.788	0.992	0.000
Mod 4 ALD ≈ 12	0.985	0.969	0.993	0.000
Mod 5 ALD ≈ 12	0.988	0.975	0.995	0.000

Mod 2 = Digital measurement of scanned wax model; Mod 3 = Digital measurement of scanned impression
Mod 4 = Digital measurement of scanned stone model; Mod 5 = Direct measurement of stone model

Bland Altman Plots

One primary application of the Bland-Altman plot is to compare two clinical measurements that each provides some errors in their measurements. The plot is the difference between the two measurements as a function of the average of the two measurements of each sample. The average of the two measurements is used because that is the best estimate of the true value. In this study, it is used to compare different measurement modalities at various levels of crowding with the “Gold Standard”. On the Bland Altman Plots, the Y-axis represents the amount of bias and the difference between the each measurement modality and the “Gold Standard”; the X-axis represents the average of the two measurements. The limits of agreement are computed which is specified as *bias ± 1.96 SD.* The Bland Altman Plots shown in Figures 13 to 32, show that the discrepancies are with in the 95% confidence interval, indicating good clinical agreement between each measurement modality and the gold standard regardless of the level of crowding. Bland Altman Plots shown in Figures 33 to 39 compare the different measurement modalities back to the “Gold Standard” and the “Clinical Standard.” The “Clinical Standard” is the measurement of stone models with digital calipers. These plots illustrate the difference in accuracy between scanning impression, stone models, and traditional methods. Table 3 shows the mean differences and the uppermost and lowermost limit of the confidence interval. The tighter the confidence interval, and the closer the mean difference line is to 0, the more accurate the modality.

Table 3. Bland Altman Parameters for the Different Measurement Modalities

		Mean Difference	95% Confidence Interval	
			Lower Bound	Upper Bound
~ 0 mm	Mod 1 vs 2	0.372	-0.307	1.051
	Mod 1 vs 3	0.155	-0.575	0.884
	Mod 1 vs 4	0.124	-0.350	0.599
	Mod 1 vs 5	0.052	-0.336	0.440
~ 3 mm	Mod 1 vs 2	0.116	-0.484	0.717
	Mod 1 vs 3	0.297	-0.362	0.957
	Mod 1 vs 4	0.041	-0.453	0.534
	Mod 1 vs 5	0.053	-0.248	0.355
~ 6 mm	Mod 1 vs 2	0.189	-0.508	0.887
	Mod 1 vs 3	0.443	-0.237	1.125
	Mod 1 vs 4	-0.116	-0.623	0.390
	Mod 1 vs 5	0.054	-0.373	0.482
~ 9 mm	Mod 1 vs 2	0.088	-0.565	0.740
	Mod 1 vs 3	0.307	-0.263	0.878
	Mod 1 vs 4	-0.077	-0.492	0.337
	Mod 1 vs 5	0.032	-0.404	0.468
~ 12 mm	Mod 1 vs 2	0.123	-0.520	0.766
	Mod 1 vs 3	0.308	-0.314	0.930
	Mod 1 vs 4	-0.015	-0.656	0.626
	Mod 1 vs 5	0.021	-0.546	0.588
Overall	Mod 1 vs 2	0.209	-0.516	0.933
	Mod 1 vs 3	0.333	-0.393	1.060
	Mod 1 vs 4	0.022	-0.555	0.599
	Mod 1 vs 5	0.073	-0.410	0.556
Overall	Mod 5 vs 2	0.135	-0.519	0.790
	Mod 5 vs 3	0.260	-0.394	0.914
	Mod 5 vs 4	-0.051	-0.586	0.484

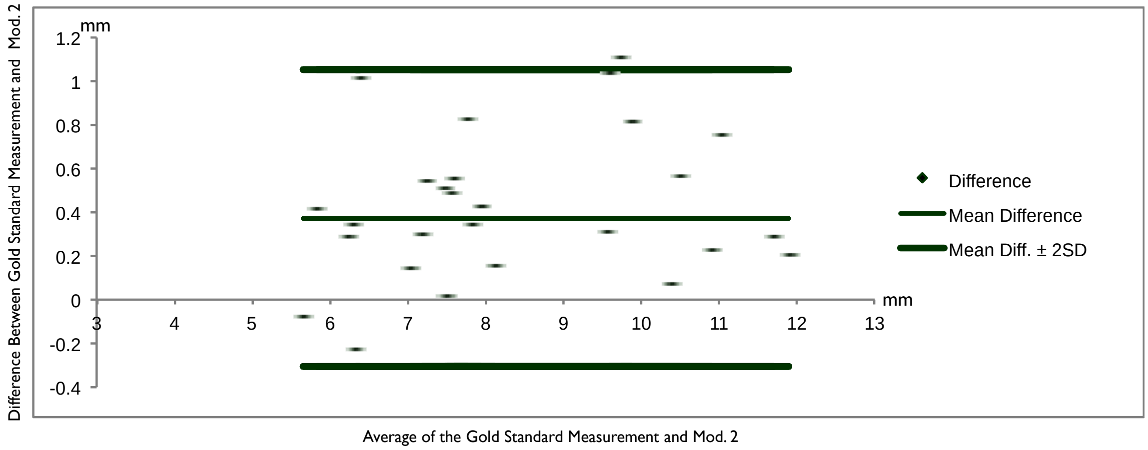

Figure 13. Bland Altman Plot of Digital Measurement on Scanned Non Crowded Wax Model versus the "Gold Standard"

Figure 14. Bland Altman Plot of Digital Measurement on Scanned Non Crowded Impression versus the "Gold Standard"

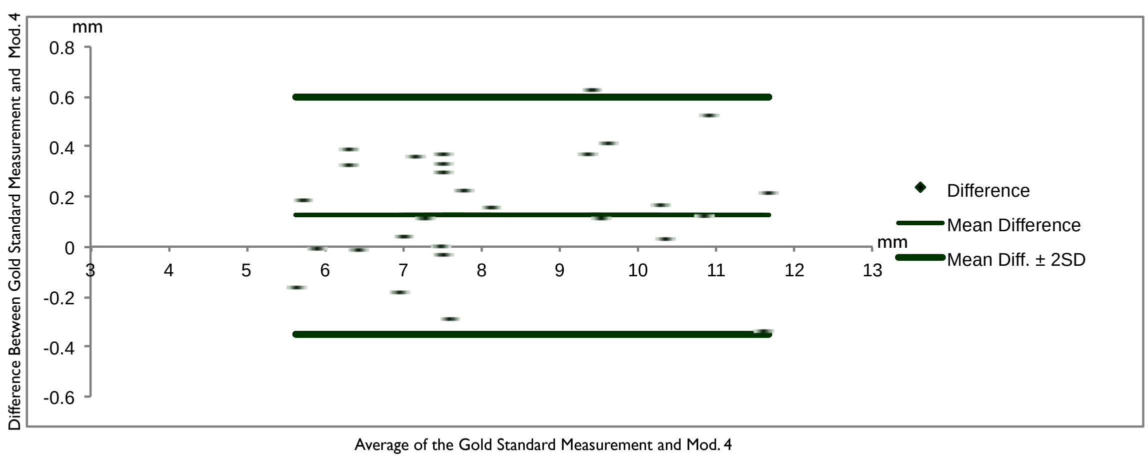

Figure 15. Bland Altman Plot of Digital Measurement on Scanned Non Crowded Stone Model versus the "Gold Standard"

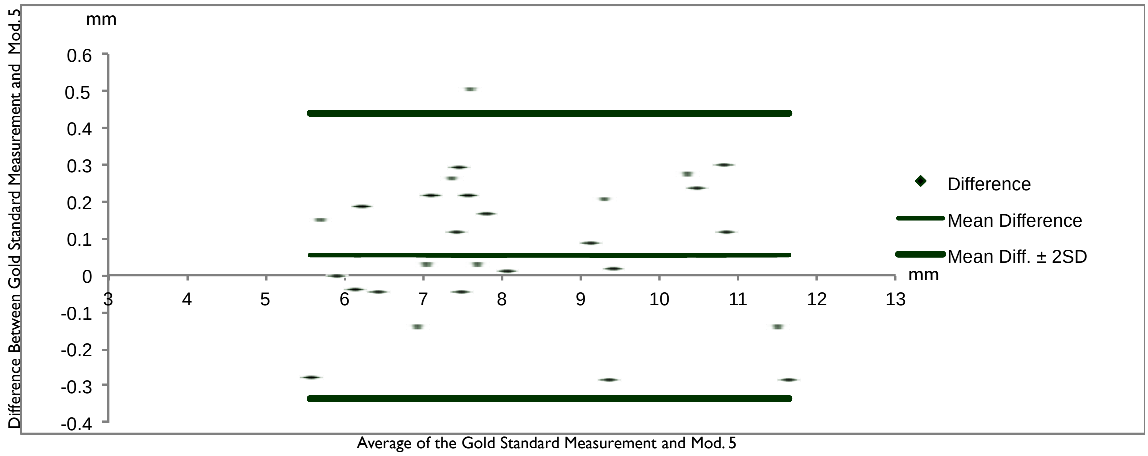

Figure 16. Bland Altman Plot of Direct Measurement on Non Crowded Stone Model versus the “Gold Standard”

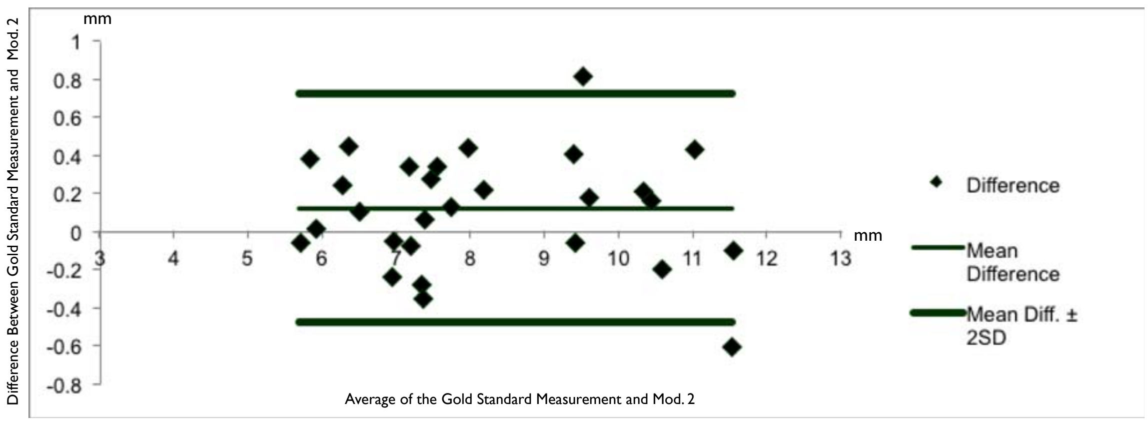

Figure 17. Bland Altman Plot of Digital Measurement on Scanned Mildly Crowded Wax Model versus the “Gold Standard”

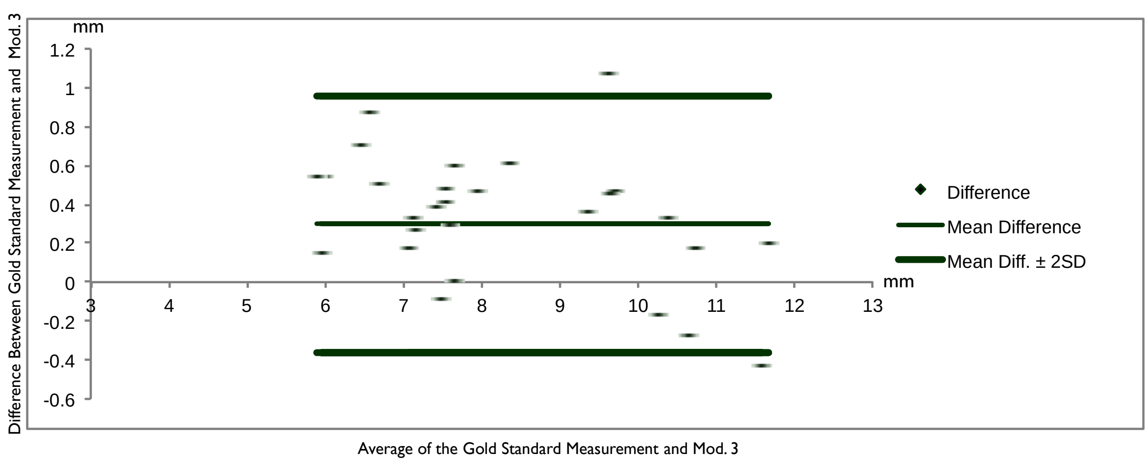

Figure 18. Bland Altman Plot of Digital Measurement on Scanned Mildly Crowded Impression versus the “Gold Standard”

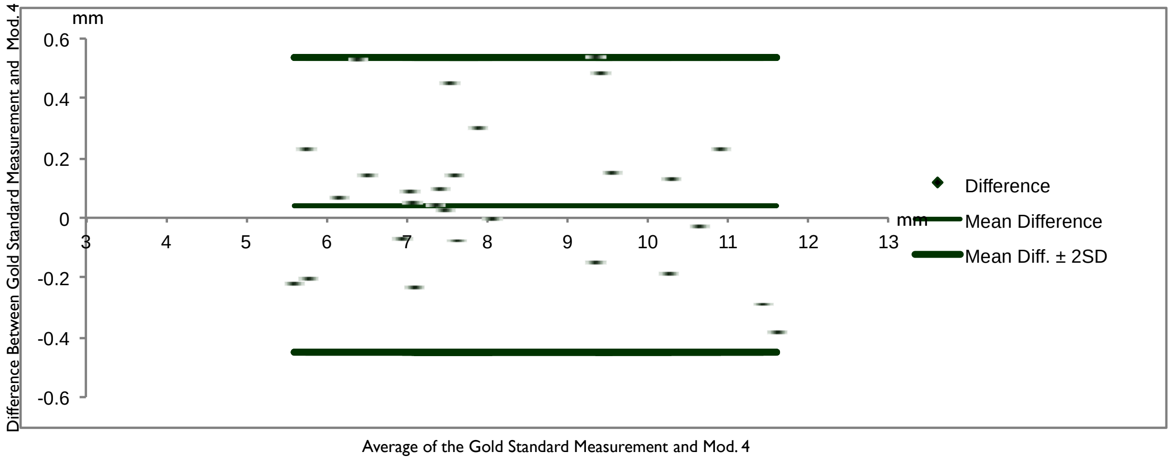

Figure 19. Bland Altman Plot of Digital Measurement on Scanned Mildly Crowded Stone Model versus the "Gold Standard"

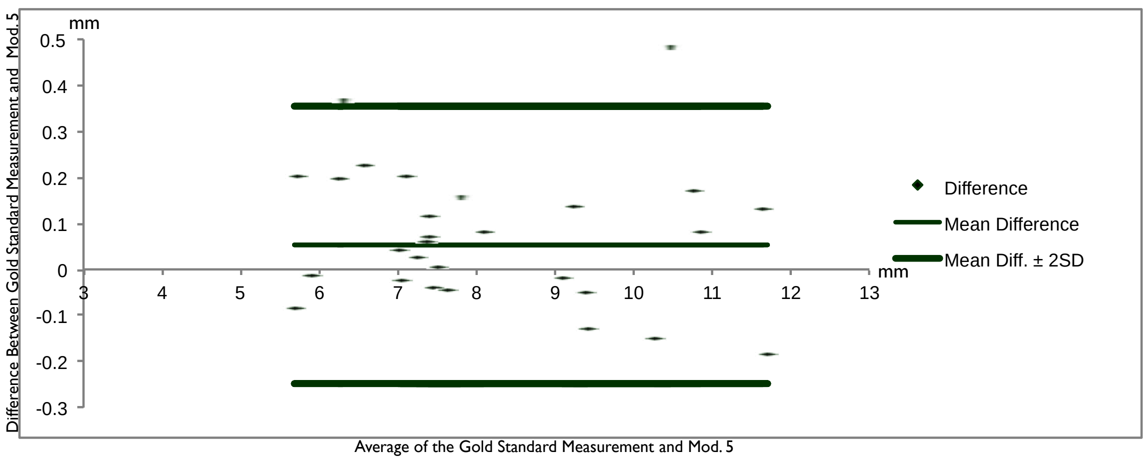

Figure 20. Bland Altman Plot of Direct Measurement on Mildly Crowded Stone Model versus the "Gold Standard"

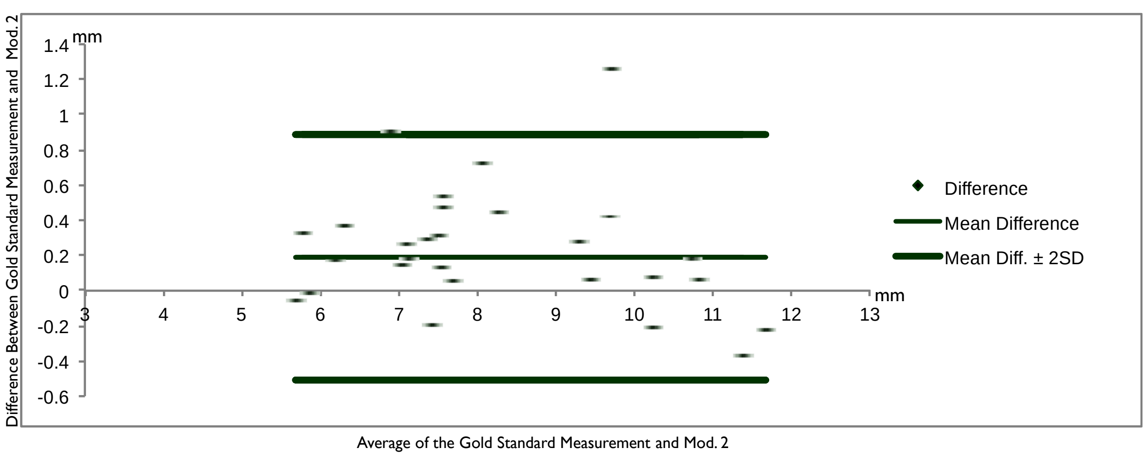

Figure 21. Bland Altman Plot of Digital Measurement on Scanned Moderately Crowded Wax Model versus the "Gold Standard"

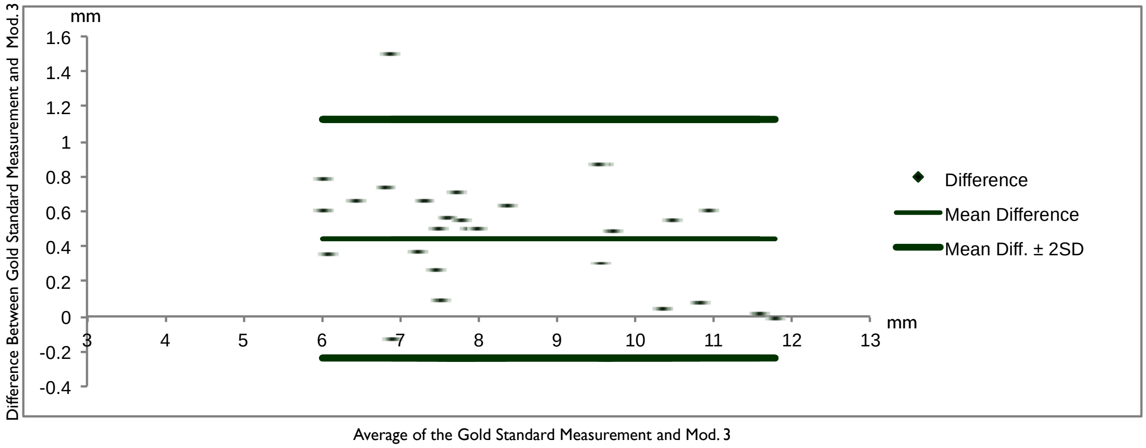

Figure 22. Figure 17. Bland Altman Plot of Digital Measurement on Scanned Moderately Crowded Impression versus the "Gold Standard"

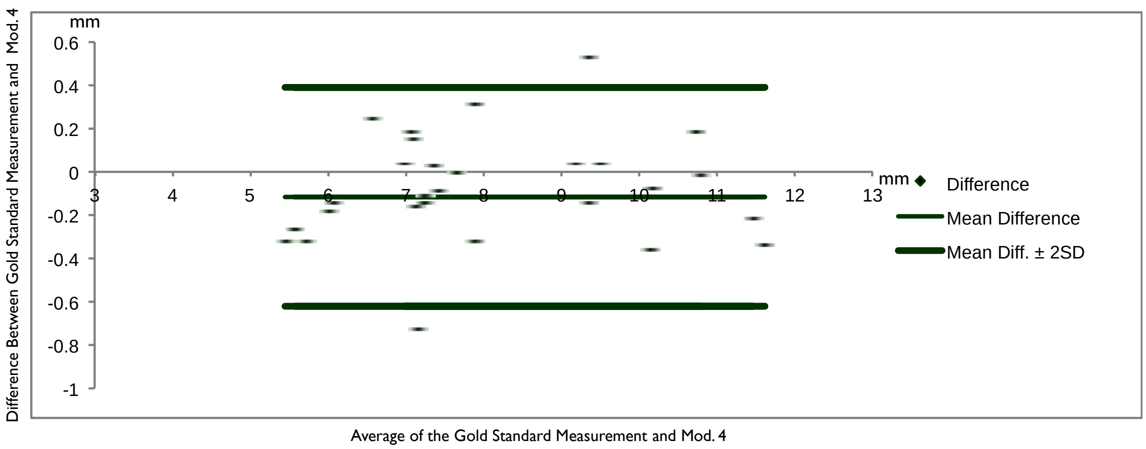

Figure 23. Bland Altman Plot of Digital Measurement on Scanned Moderately Crowded Stone Model versus the "Gold Standard"

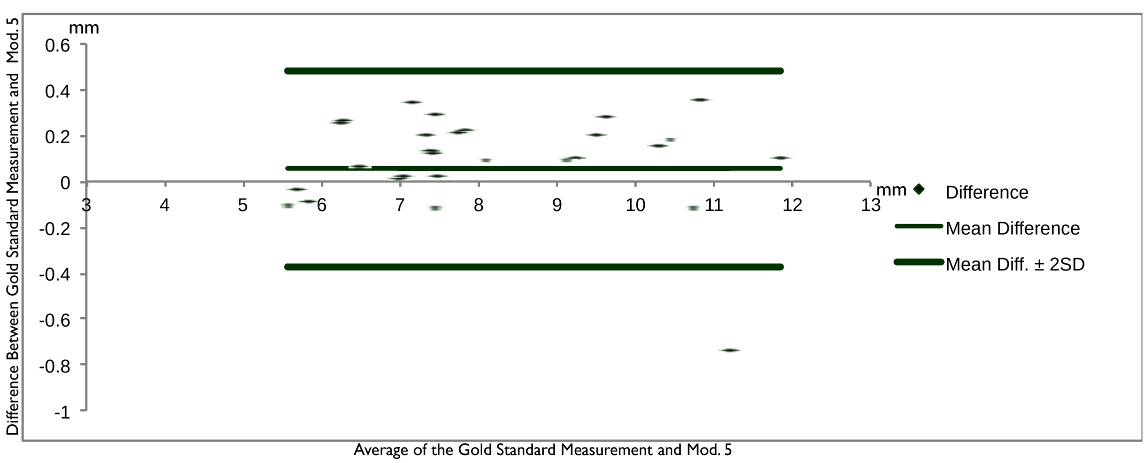

Figure 24. Bland Altman Plot of Direct Measurement on Moderately Crowded Stone Model versus the "Gold Standard"

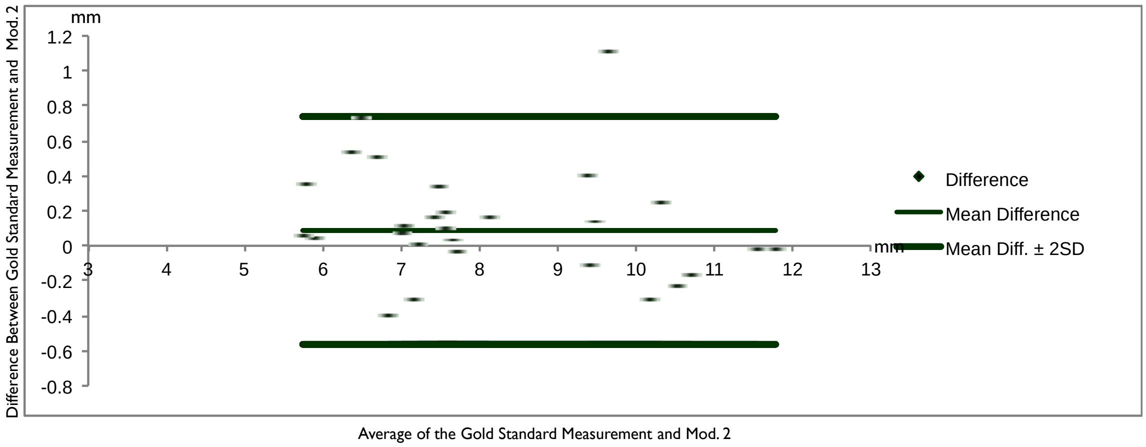

Figure 25. Bland Altman Plot of Digital Measurement on Scanned Severely Crowded Wax Model versus the "Gold Standard"

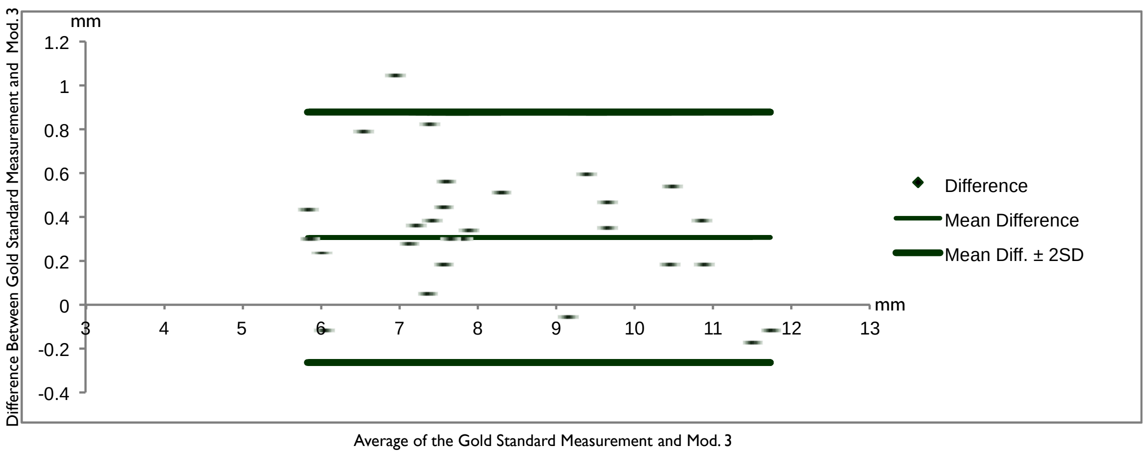

Figure 26. Bland Altman Plot of Digital Measurement on Scanned Severely Crowded Impression versus the "Gold Standard"

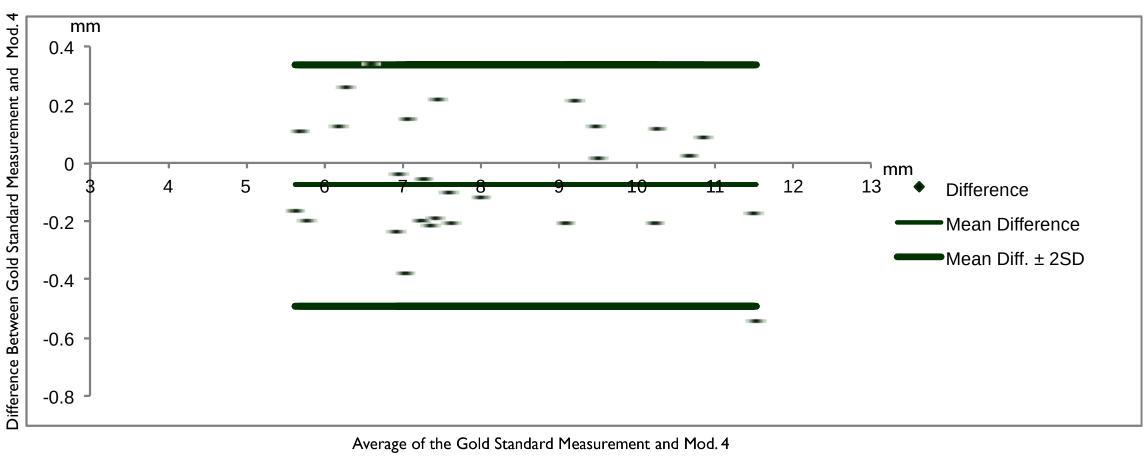

Figure 27. Bland Altman Plot of Digital Measurement on Scanned Severely Crowded Stone Model versus the "Gold Standard"

Figure 28. Bland Altman Plot of Direct Measurement on Severely Crowded Stone Model versus the "Gold Standard"

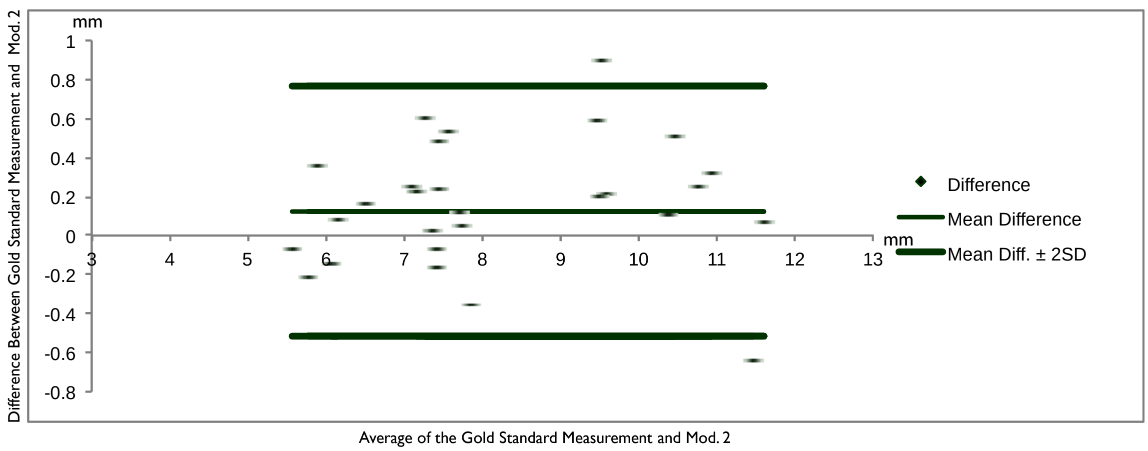

Figure 29. Bland Altman Plot of Digital Measurement on Scanned Extremely Severe Crowded Wax Model versus the "Gold Standard"

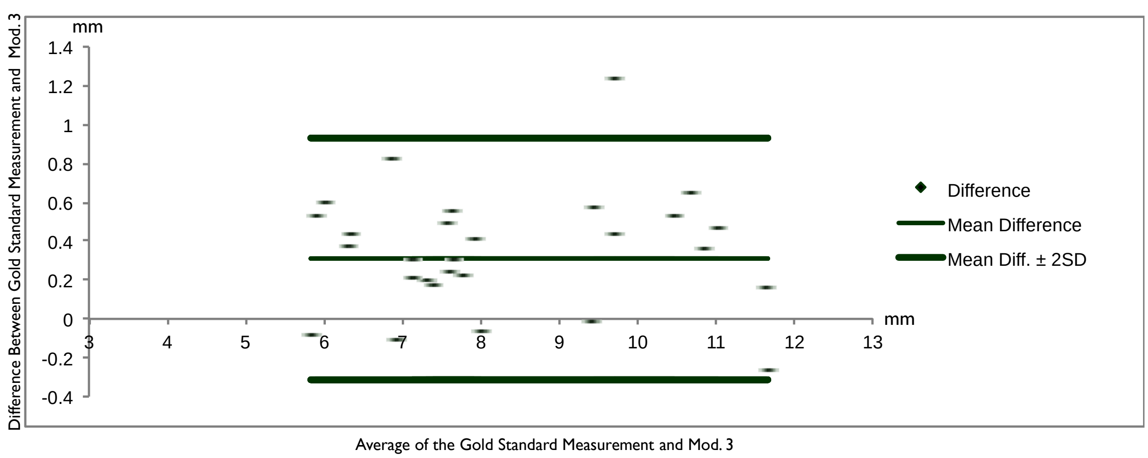

Figure 30. Bland Altman Plot of Digital Measurement on Scanned Extremely Severe Crowded Impression versus the "Gold Standard"

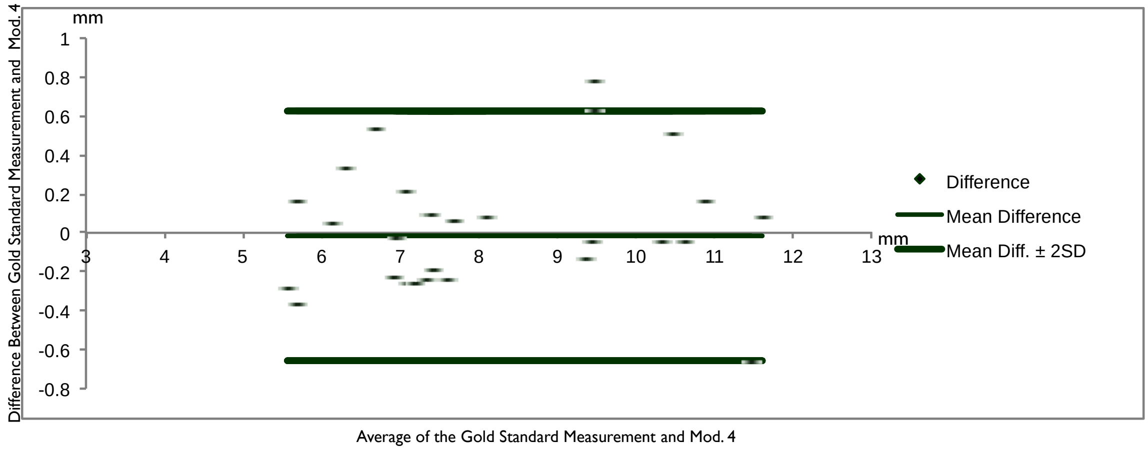

Figure 31. Bland Altman Plot of Digital Measurement on Scanned Extremely Severe Crowded Stone Model versus the "Gold Standard"

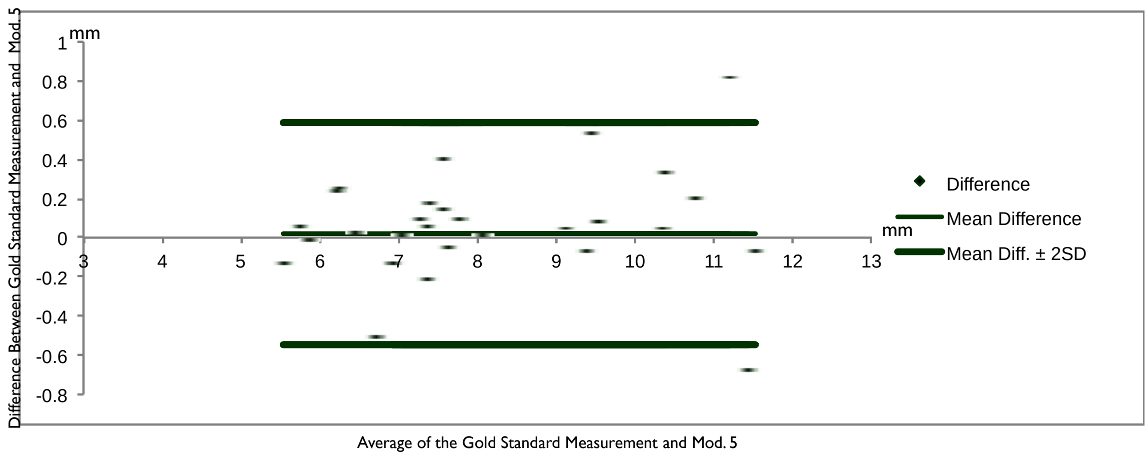

Figure 32. Bland Altman Plot of Direct Measurement on Extremely Severe Crowded Stone Model versus the "Gold Standard"

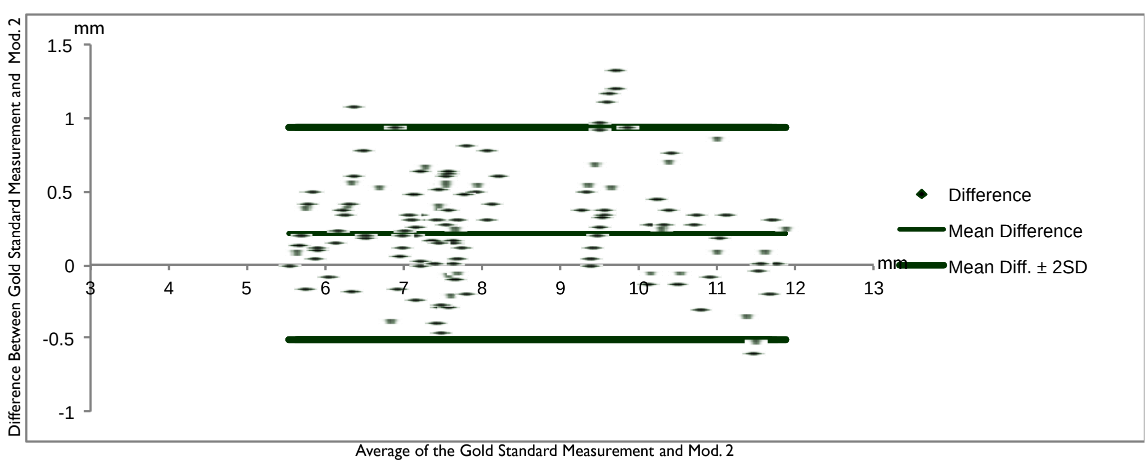

Figure 33. Bland Altman Plot of Overall Digital Measurements on Scanned Wax Models versus the "Gold Standard"

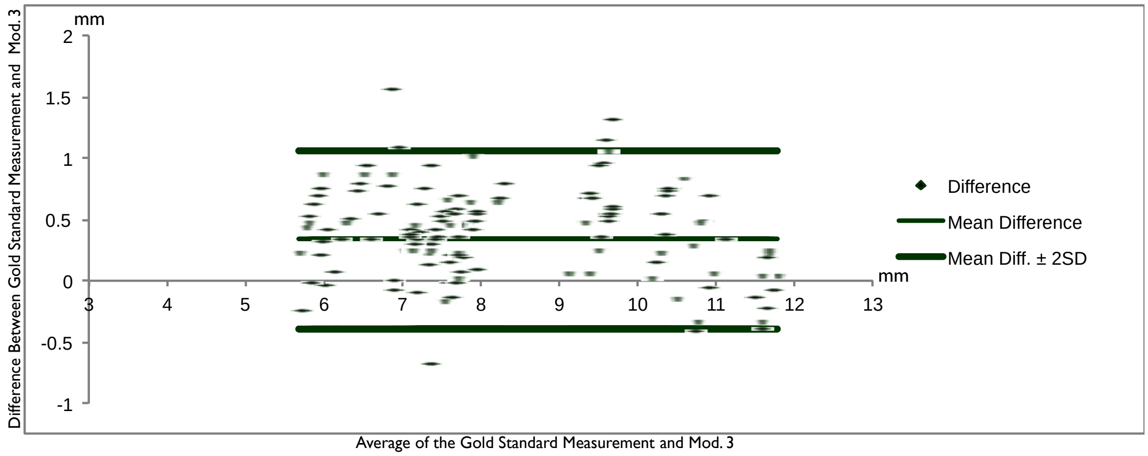

Figure 34. Bland Altman Plot of Overall Digital Measurements on Scanned Impressions versus the "Gold Standard"

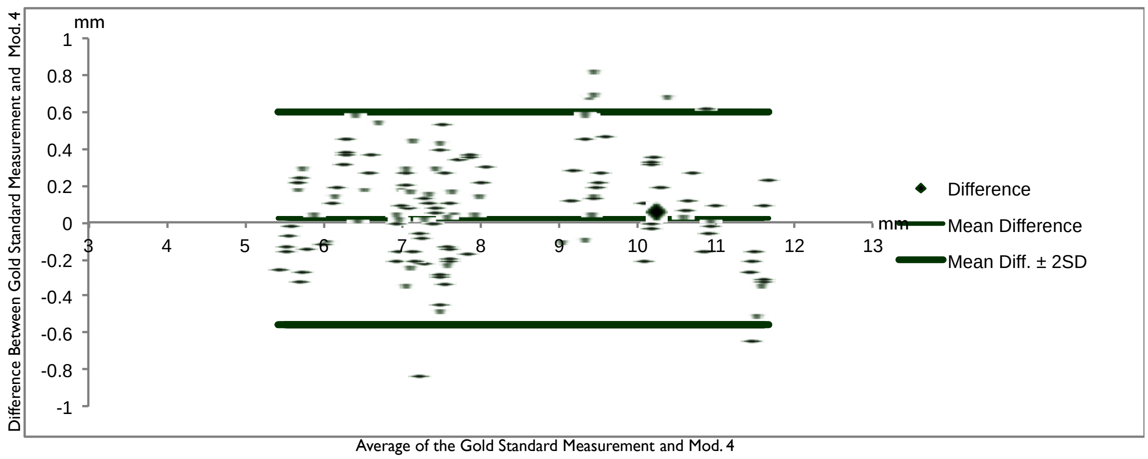

Figure 35. Bland Altman Plot of Overall Digital Measurements on Scanned Stone Models versus the "Gold Standard"

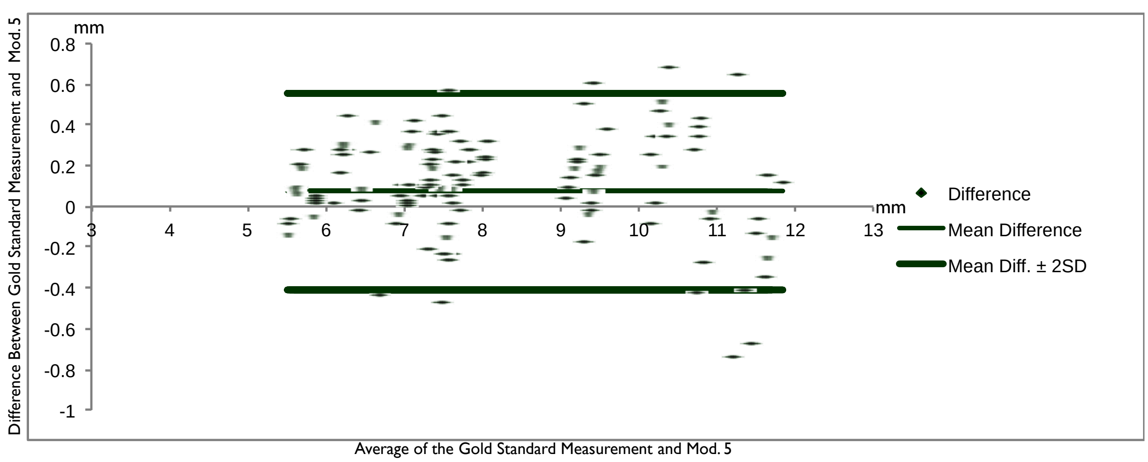

Figure 36. Bland Altman Plot of Overall Direct Measurements on Stone Models versus the "Gold Standard"

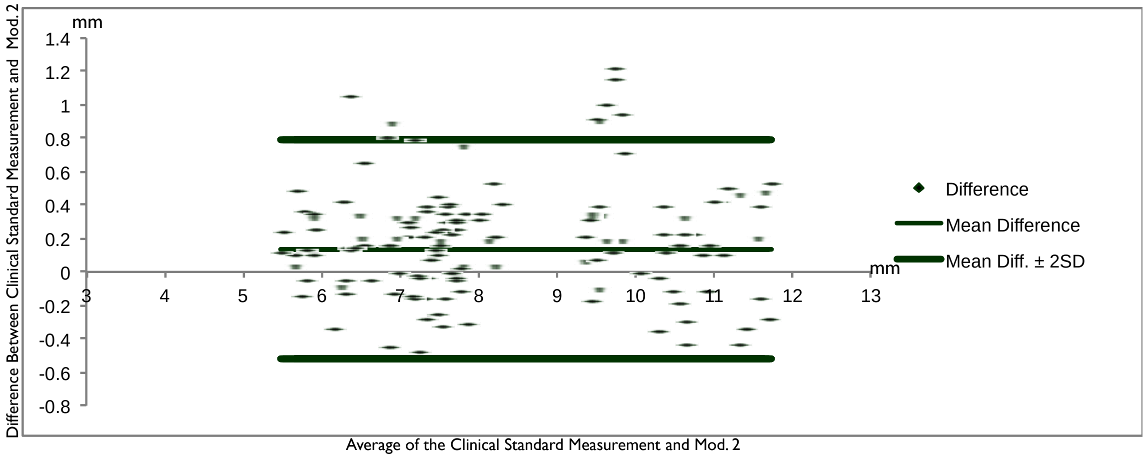

Figure 37. Bland Altman Plot of Overall Digital Measurements on Scanned Wax Models versus the "Clinical Standard"

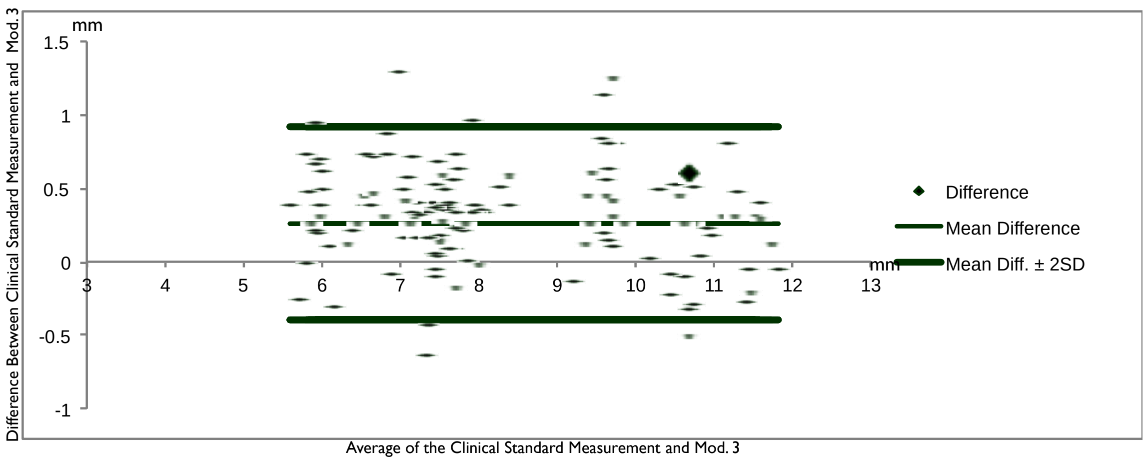

Figure 38. Bland Altman Plot of Overall Digital Measurements on Scanned Impressions versus the "Clinical Standard"

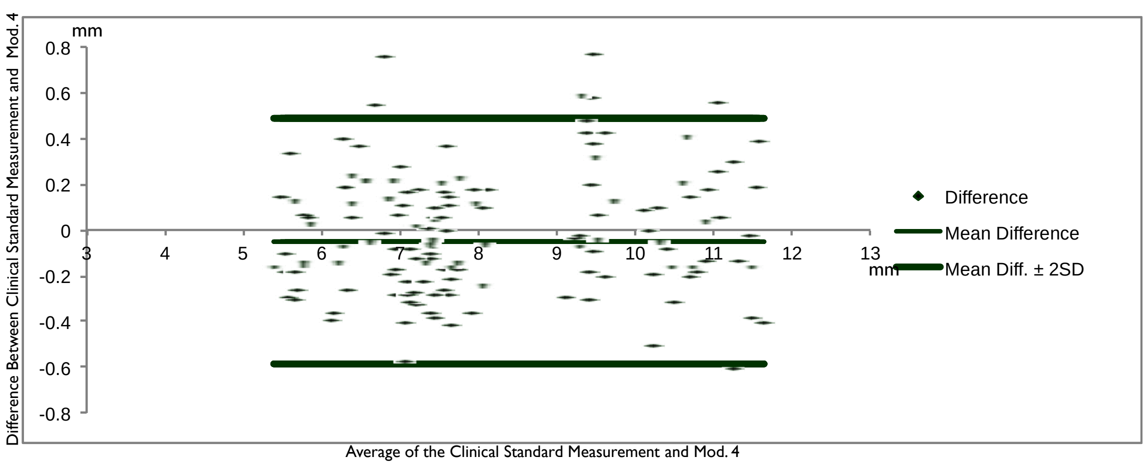

Figure 39. Bland Altman Plot of Overall Digital Measurements on Scanned Stone Models versus the "Clinical Standard"

CHAPTER FIVE

DISCUSSION

The overall ICC results suggest excellent agreement and correlation among the digital model measurements and stone model measurements with the reference measurements. These results were both clinically and statistically significant. These findings coincide with Zilberman's study[17] which showed that there were high correlation and agreement between the OrthoCad digital models and "Gold Standard" in all measurement methods. Also consistent were the results showing that measurements made directly on the stone model with a digital caliper were superior in accuracy compared to the other modalities.

While the ICC demonstrated good agreement between all measurement modalities and the gold standard, it could not confirm the accuracy of each modality. By using the means of the 2 measurement modalities against their differences, Bland Altman Plots provide the visual of the differences or lack thereof between the 2 measurement modalities. As each modality was plotted against the "Gold Standard", the magnitude of mean difference and the limits of agreement (±1.96 SD) essentially indicate the accuracy of individual measurement modality. The greatest mean differences in all levels of crowding, except for the non-crowded situation, observed in the digital measurement of impression (Mod 3) implied that this is the least accurate measurement modality (Table 3; Figures 34,38). This is likely due to the fact that negative scanning of the impression is technique sensitive as the laser of the scanner was consistently unable to capture the incisal edges of the anterior teeth. Furthermore, polyvinyl siloxane impression material was used in this study instead of irreversible hydrocolloid because it has been proven to be more accurate and less affected by humidity.[33] However, the scanner was originally calibrated for irreversible hydrocolloid impression material, and had to be recalibrated, which changed the scanning time and exposure in order for the laser to produce an accurate scan. Since the scans theoretically seem to produce better results on dull surfaces, the inherent shine of a polyvinyl siloxane impression compared to the dull surface of irreversible hydrocolloid impression material may affect the overall accuracy.

The Bland Altman Plots demonstrated that the digital measurement of the wax model (Mod 2) was the second least accurate modality (Table 3; Figures 33,37). This result is surprising as Mod 2 entailed the least processing variables compared to other modalities. Similar to the impression scan, the surface texture of the plastic teeth, even though microabraded, and/or the wax might affect the quality of the scanned image resulting in inaccurate measurements. While Mod 2 was intended to represent intra-oral scanning, it has no clinical application. When a full-arch intra-oral scanner with an acceptable quality is available, digital measurement of the intra-oral scanned images can be compared with other measurement modalities.

Digital and direct measurements stone model (Mod 4 & 5) are the most accurate measurement methods when compared to the “Gold Standard” (Table 3, Figures 35,36). While additional time is required for stone model fabrication, this is offset by the superior measurement accuracy achieved in Mod 4 & 5. Furthermore, the negative impression scanning is more technique sensitive and requires almost twice as much time to scan than the stone model. When Mod 4 and Mod 5 were compared between themselves (Table 3,

Figure 39), low mean difference and limits of agreement indicate that both modalities are comparable. As “Gold Standard” is unattainable clinically, Mod 4 and/or Mod 5 can be used as controlled when evaluating method of measuring MD tooth size.

An effort was also made in this study to make the measurements as accurate as possible with less attention to the time spent for measuring. The software has a function that automatically determines the contact points and uses them to estimate the MD tooth width. However, the distance between the contact points does not always represent the MD tooth width. Therefore, the computer generated MD contact points were not immediately used but rather manipulated first (by magnification and rotation) in order to obtain the best points of measurement. In a clinical setting, this step adds time, but it ensures a higher level of accuracy.

This study suggests that digital measurement of MD tooth width using Ortho Insight 3D is a viable option for orthodontists. The accuracy of digital measurement of the scanned stone model appears to be comparable to that of direct measurement of the stone model with a caliper. This allows orthodontists to use the software to perform measurements, Bolton Analysis, occlusal evaluation, object segmentation, and diagnostic virtual tooth set-ups, which will aid in the diagnostic and treatment planning process. Furthermore, use of the Ortho Insight 3D also enables the orthodontist to store patient models digitally, which is very attractive because it saves space, time, and money.

Conclusions

The null hypothesis was rejected, and significant correlation and agreement in measurements of MD tooth widths on the Ortho Insight 3D scanner with the “Gold

Standard” was proven.

The results of this study indicate that the following conclusions can be made:

1. Based upon the Cronbach Alphas for reliability, each of the measurement modalities in this study is repeatable.
2. Based upon ICC values, regardless of the level of crowding, all measurement modalities show strong correlation and agreement to the “Gold Standard”.
3. Based upon the accuracy observed in this study, the traditional measurement method using a digital caliper on stone models and digitally measuring scanned stone models are superior to the measurements made on digital models produced by impressions scanned by the Ortho Insight 3D.
4. Digital models may be considered as sufficient alternatives to traditional models with respect to mesial distal tooth measurement in orthodontic practice, but for the highest accuracy, the stone model should be scanned instead of the impressions.
5. Results of this study warrant further investigation to determine the clinical and practice parameters that would influence the accuracy of digital models compared the traditional model.

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APPENDIX A

MAIN DATA

Hand measurements
* all measurements in mm

Degree of Crowding	Tooth	Model (Caliper)	Model Scan	Impression Scan	Cast Scan	Cast (Caliper)
None	UR7	9.12	10.26	10.11	9.53	9.37
None	UR6	10.97	11	10.55	10.9	10.9
None	UR5	6.95	7.09	7.33	7	6.82
None	UR4	7.73	7.46	6.97	7.45	7.67
None	UR3	7.93	8.18	8.5	8.19	8.05
None	UR2	7.23	7.71	7.45	7.31	7.47
None	UR1	9.41	10.28	9.58	9.58	9.19
None	UL1	9.39	9.7	9.81	9.81	9.42
None	UL2	7.27	7.84	7.1	7.66	7.59
None	UL3	7.7	8.13	7.82	7.42	7.88
None	UL4	7.56	7.97	7.7	7.86	7.67
None	UL5	7.04	7.31	7.3	6.83	7.05
None	UL6	10.05	10.75	10.67	10.36	10.48
None	UL7	9.06	10.1	9.7	9.7	9.16
None	LL7	10.6	11.39	10.37	11.17	10.95
None	LL6	11.8	11.98	11.39	11.44	11.5
None	LL5	7.29	7.79	7.57	7.64	7.82
None	LL4	6.92	7.49	7.46	7.32	7.18
None	LL3	6.11	6.45	6.12	6.44	6.08
None	LL2	6.07	6.37	6.34	6.48	6.28
None	LL1	5.58	6.01	5.94	5.78	5.75
None	LR1	5.6	5.61	5.75	5.53	5.42
None	LR2	5.86	6.87	5.55	5.86	5.87
None	LR3	6.44	6.19	6.71	6.4	6.38
None	LR4	7.41	8.15	8.36	7.63	7.46
None	LR5	7.64	7.5	7.54	7.46	7.45
None	LR6	11.59	11.84	11.76	11.77	11.42
None	LR7	10.21	10.39	10.28	10.36	10.57

Degree of Crowding	Tooth	Model (Caliper)	Model Scan	Impression Scan	Cast Scan	Cast (Caliper)
Mild	UR7	9.12	9.6	9.51	9.65	9.31
Mild	UR6	10.97	11.24	10.49	11.01	10.87
Mild	UR5	6.95	6.94	7.12	6.89	7.01
Mild	UR4	7.73	7.2	7.73	7.48	7.42
Mild	UR3	7.93	8.29	8.64	8.03	8.13
Mild	UR2	7.23	7.16	7.58	6.97	7.24
Mild	UR1	9.41	9.68	9.93	9.63	9.35
Mild	UL1	9.39	9.37	9.85	9.25	9.36
Mild	UL2	7.27	7.6	7.76	7.75	7.42
Mild	UL3	7.7	8.18	8.17	8.02	7.88
Mild	UL4	7.56	7.8	7.63	7.56	7.6
Mild	UL5	7.04	6.81	7.27	7.07	7
Mild	UL6	10.05	10.44	10.52	10.33	10.69
Mild	UL7	9.06	9.92	10.14	9.61	9.06
Mild	LL7	10.6	10.48	10.81	10.62	10.83
Mild	LL6	11.8	11.21	11.34	11.4	11.61
Mild	LL5	7.29	7.4	7.71	7.35	7.38
Mild	LL4	6.92	7.33	7.27	7.05	7.17
Mild	LL3	6.11	6.39	6.97	6.65	6.32
Mild	LL2	6.07	6.57	6.79	6.16	6.47
Mild	LL1	5.58	6.01	6.13	5.83	5.81
Mild	LR1	5.6	5.67	6.23	5.48	5.62
Mild	LR2	5.86	5.91	6	5.67	5.86
Mild	LR3	6.44	6.56	6.91	6.57	6.66
Mild	LR4	7.41	7.71	7.92	7.44	7.42
Mild	LR5	7.64	7.17	7.4	7.64	7.51
Mild	LR6	11.59	11.49	11.75	11.27	11.7
Mild	LR7	10.21	10.52	10.15	10.15	10.19

Degree of Crowding	Tooth	Model (Caliper)	Model Scan	Impression Scan	Cast Scan	Cast (Caliper)
Moderate	UR7	9.12	9.42	10.01	9.19	9.26
Moderate	UR6	10.97	10.82	10.84	10.76	10.65
Moderate	UR5	6.95	7.2	6.81	6.99	6.96
Moderate	UR4	7.73	7.56	7.53	7.35	7.46
Moderate	UR3	7.93	8.47	8.65	7.71	8.12
Moderate	UR2	7.23	7.48	7.69	7.03	7.4
Moderate	UR1	9.41	9.88	9.94	9.5	9.75
Moderate	UL1	9.39	9.44	9.68	9.25	9.6
Moderate	UL2	7.27	7.82	7.85	7.17	7.58
Moderate	UL3	7.7	8.41	8.2	8.01	7.93
Moderate	UL4	7.56	7.67	8.12	7.62	7.84
Moderate	UL5	7.04	7.18	7.37	7.16	7.03
Moderate	UL6	10.05	10.26	10.74	10.11	10.35
Moderate	UL7	9.06	10.32	9.93	9.6	9.16
Moderate	LL7	10.6	10.81	11.23	10.82	10.99
Moderate	LL6	11.8	11.54	11.76	11.43	11.88
Moderate	LL5	7.29	7.77	7.55	7.16	7.43
Moderate	LL4	6.92	7.08	7.6	7.14	7.3
Moderate	LL3	6.11	6.46	7.6	5.96	6.37
Moderate	LL2	6.07	6.24	6.73	5.9	6.34
Moderate	LL1	5.58	5.91	6.37	5.27	5.48
Moderate	LR1	5.6	5.63	6.29	5.42	5.65
Moderate	LR2	5.86	5.84	6.21	5.54	5.77
Moderate	LR3	6.44	7.31	7.14	6.66	6.48
Moderate	LR4	7.41	7.63	8.03	7.35	7.45
Moderate	LR5	7.64	7.28	8.03	6.75	7.37
Moderate	LR6	11.59	11.17	11.56	11.33	10.81
Moderate	LR7	10.21	10.1	10.36	9.96	10.51

Degree of Crowding	Tooth	Model (Caliper)	Model Scan	Impression Scan	Cast Scan	Cast (Caliper)
Severe	UR7	9.12	9.55	9.1	8.96	9.3
Severe	UR6	10.97	10.6	10.95	10.87	10.5
Severe	UR5	6.95	7.01	7.23	7.11	6.87
Severe	UR4	7.73	7.62	7.63	7.24	7.42
Severe	UR3	7.93	8.18	8.54	7.92	8.21
Severe	UR2	7.23	7.19	7.58	6.83	7.28
Severe	UR1	9.41	9.34	9.82	9.49	9.57
Severe	UL1	9.39	9.52	9.86	9.53	9.5
Severe	UL2	7.27	7.61	7.85	7.24	7.67
Severe	UL3	7.7	7.67	8.05	7.51	7.77
Severe	UL4	7.56	7.65	7.93	7.54	7.74
Severe	UL5	7.04	6.6	7.37	6.78	7.11
Severe	UL6	10.05	10.43	10.73	10.32	10.26
Severe	UL7	9.06	10.17	9.66	9.29	9.52
Severe	LL7	10.6	10.4	11.02	10.67	10.9
Severe	LL6	11.8	11.75	11.65	11.24	11.41
Severe	LL5	7.29	6.98	7.35	7.53	7.51
Severe	LL4	6.92	7.05	7.78	6.92	7.25
Severe	LL3	6.11	6.83	6.9	6.38	6.23
Severe	LL2	6.07	6.61	5.96	6.22	6.33
Severe	LL1	5.58	5.93	6.03	5.71	5.62
Severe	LR1	5.6	5.74	5.99	5.53	5.84
Severe	LR2	5.86	5.9	6.1	5.67	5.85
Severe	LR3	6.44	6.91	7.46	6.76	6.81
Severe	LR4	7.41	7.49	7.78	7.14	7.16
Severe	LR5	7.64	7.58	7.79	7.31	7.45
Severe	LR6	11.59	11.53	11.38	11.39	11.13
Severe	LR7	10.21	10.01	10.51	10.13	10.08

Degree of Crowding	Tooth	Model (Caliper)	Model Scan	Impression Scan	Cast Scan	Cast (Caliper)
Extremely Severe	UR7	9.12	9.74	9.72	9.77	9.68
Extremely Severe	UR6	10.97	11.09	11.24	10.93	11.58
Extremely Severe	UR5	6.95	7.55	7.25	6.92	6.82
Extremely Severe	UR4	7.73	7.37	7.68	7.2	7.22
Extremely Severe	UR3	7.93	7.67	7.96	8.1	8.04
Extremely Severe	UR2	7.23	7.68	7.39	6.93	7.29
Extremely Severe	UR1	9.41	9.67	9.89	9.41	9.54
Extremely Severe	UL1	9.39	9.59	9.37	9.25	9.31
Extremely Severe	UL2	7.27	7.81	7.45	7.38	7.46
Extremely Severe	UL3	7.7	7.75	8.11	7.46	7.79
Extremely Severe	UL4	7.56	7.74	7.85	7.68	7.57
Extremely Severe	UL5	7.04	7.23	7.21	6.78	7.02
Extremely Severe	UL6	10.05	10.69	10.71	10.69	10.52
Extremely Severe	UL7	9.06	9.96	10.3	9.84	9.11
Extremely Severe	LL7	10.6	10.88	11	10.58	10.83
Extremely Severe	LL6	11.8	11.13	11.51	11.11	11.09
Extremely Severe	LL5	7.29	7.53	7.79	7.03	7.35
Extremely Severe	LL4	6.92	7.19	6.84	7.16	6.44
Extremely Severe	LL3	6.11	5.96	6.54	6.43	6.35
Extremely Severe	LL2	6.07	6.16	6.46	6.13	6.31
Extremely Severe	LL1	5.58	5.51	6.12	5.75	5.45
Extremely Severe	LR1	5.6	6.04	6.29	5.4	5.74
Extremely Severe	LR2	5.86	5.64	5.77	5.49	5.84
Extremely Severe	LR3	6.44	6.57	7.24	6.94	6.43
Extremely Severe	LR4	7.41	7.35	7.88	7.42	7.73
Extremely Severe	LR5	7.64	7.31	7.78	7.29	7.62
Extremely Severe	LR6	11.59	11.62	11.71	11.63	11.48
Extremely Severe	LR7	10.21	10.42	10.97	10.27	10.36

APPENDIX B

RELIABILITY DATA

Tooth Measurements

*all measurements in mm

* T = time point

Tooth	T1 Model (Caliper)	T2 Model (Caliper)	T3 Model (Caliper)	T4 Model (Caliper)
UR7	9.12	9.17	9.2	9.27
UR6	10.97	10.75	10.7	10.81
UR5	6.95	7	7.01	6.99
UR4	7.73	7.44	7.35	7.39
UR3	7.93	8.1	8.08	8.15
UR2	7.23	7.27	7.21	7.22
UR1	9.41	9.53	9.56	9.5
UL1	9.39	9.39	9.44	9.49
UL2	7.27	7.3	7.39	7.33
UL3	7.7	7.75	7.8	7.71
UL4	7.56	7.67	7.7	7.73
UL5	7.04	7.06	7.07	7.01
UL6	10.05	10.25	10.38	10.23
UL7	9.06	9.05	9.11	9.18
LL7	10.6	10.67	10.69	10.74
LL6	11.8	11.82	11.82	11.81
LL5	7.29	7.38	7.33	7.35
LL4	6.92	7.03	6.95	7.05
LL3	6.11	6.18	6.14	6.14
LL2	6.07	6.17	6.13	6.11
LL1	5.58	5.63	5.63	5.67
LR1	5.6	5.71	5.8	5.79
LR2	5.86	5.86	5.99	5.87
LR3	6.44	6.53	6.49	6.34
LR4	7.41	7.38	7.33	7.34
LR5	7.64	7.55	7.44	7.46
LR6	11.59	11.47	11.63	11.66
LR7	10.21	10.29	10.42	10.52

Cast Measurements

Time Point	Tooth	None	Mild	Moderate	Severe	Extremely Severe
1	UR7	9.37	9.31	9.26	9.3	9.68
1	UR6	10.9	10.87	10.65	10.5	11.58
1	UR5	6.82	7.01	6.96	6.87	6.82
1	UR4	7.67	7.42	7.46	7.42	7.22
1	UR3	8.05	8.13	8.12	8.21	8.04
1	UR2	7.47	7.24	7.4	7.28	7.29
1	UR1	9.19	9.35	9.75	9.57	9.54
1	UL1	9.42	9.36	9.6	9.5	9.31
1	UL2	7.59	7.42	7.58	7.67	7.46
1	UL3	7.88	7.88	7.93	7.77	7.79
1	UL4	7.67	7.6	7.84	7.74	7.57
1	UL5	7.05	7	7.03	7.11	7.02
1	UL6	10.48	10.69	10.35	10.26	10.52
1	UL7	9.16	9.06	9.16	9.52	9.11
1	LL7	10.95	10.83	10.99	10.9	10.83
1	LL6	11.5	11.61	11.88	11.41	11.09
1	LL5	7.82	7.38	7.43	7.51	7.35
1	LL4	7.18	7.17	7.3	7.25	6.44
1	LL3	6.08	6.32	6.37	6.23	6.35
1	LL2	6.28	6.47	6.34	6.33	6.31
1	LL1	5.75	5.81	5.48	5.62	5.45
1	LR1	5.42	5.62	5.65	5.84	5.74
1	LR2	5.87	5.86	5.77	5.85	5.84
1	LR3	6.38	6.66	6.48	6.81	6.43
1	LR4	7.46	7.42	7.45	7.16	7.73
1	LR5	7.45	7.51	7.37	7.45	7.62
1	LR6	11.42	11.7	10.81	11.13	11.48
1	LR7	10.57	10.19	10.51	10.08	10.36
2	UR7	9.62	9.47	9.58	9.7	9.64
2	UR6	11.13	10.87	10.91	10.45	10.93
2	UR5	6.68	7.06	6.56	6.87	6.78
2	UR4	7.24	7.18	7.29	7.38	7.23
2	UR3	7.98	8.11	8.07	8.16	7.96
2	UR2	7.1	7.09	7.6	7.22	7.38
2	UR1	9.27	9.24	9.47	9.61	9.52
2	UL1	9.14	9.33	9.3	9.33	9.46
2	UL2	7.34	7.42	7.44	7.42	7.44
2	UL3	7.68	7.93	7.87	7.91	7.73
2	UL4	7.66	7.5	7.58	7.72	7.58

2	**UL5**	**7.04**	**7**	**6.91**	**6.9**	**7**
2	**UL6**	**10.16**	**10.42**	**10.38**	**10.17**	**10.25**
2	**UL7**	**9.02**	**9.17**	**9.45**	**9.56**	**9.41**
2	**LL7**	**10.75**	**11**	**10.77**	**10.69**	**10.88**
2	**LL6**	**11.11**	**11.46**	**11.73**	**11.37**	**10.99**
2	**LL5**	**7.42**	**7.34**	**7.41**	**7.76**	**7.4**
2	**LL4**	**7.23**	**7.43**	**7.2**	**7.15**	**7.33**
2	**LL3**	**6.16**	**6.36**	**6.41**	**6.23**	**6.25**
2	**LL2**	**6.13**	**6.2**	**6.33**	**6.19**	**6.26**
2	**LL1**	**5.71**	**5.67**	**5.64**	**5.43**	**5.39**
2	**LR1**	**5.51**	**5.55**	**5.65**	**5.73**	**5.74**
2	**LR2**	**5.7**	**6.08**	**5.89**	**5.82**	**5.89**
2	**LR3**	**6.29**	**6.52**	**6.52**	**6.82**	**6.54**
2	**LR4**	**7.41**	**7.58**	**7.57**	**7.22**	**7.54**
2	**LR5**	**7.3**	**7.59**	**7.34**	**7.49**	**7.62**
2	**LR6**	**11.66**	**11.72**	**11.23**	**11.47**	**11.07**
2	**LR7**	**10.31**	**10.16**	**10.57**	**10.28**	**10.48**

Digital Model Measurements

Time Point	Tooth	M/D Wax Model	Impression	Poured Impression
1	UR7	9.42	10.01	9.19
1	UR6	10.82	10.84	10.76
1	UR5	7.2	6.81	6.99
1	UR4	7.56	7.53	7.35
1	UR3	8.47	8.65	7.71
1	UR2	7.48	7.69	7.03
1	UR1	9.44	9.94	9.5
1	UL1	7.82	9.68	9.25
1	UL2	8.41	7.85	7.17
1	UL3	7.67	8.2	8.01
1	UL4	7.18	8.12	7.62
1	UL5	10.26	7.37	7.16
1	UL6	10.32	10.74	10.11
1	UL7	9.44	9.93	9.6

2	UR7	9.35	9.43	8.86
2	UR6	10.91	10.93	10.71
2	UR5	7.14	7	6.73
2	UR4	7.2	7.56	7.23
2	UR3	8.4	8.7	7.84
2	UR2	7.33	7.57	7.1
2	UR1	9.99	10.06	9.54
2	UL1	9.34	9.68	9.27
2	UL2	7.78	7.71	7.08
2	UL3	8.16	8.34	7.88
2	UL4	7.52	7.84	7.6
2	UL5	7.21	7.37	7.01
2	UL6	10.46	11.01	10.28
2	UL7	10.15	9.94	9.43