EVALUATION OF THE DENTAL CASTS MEASUREMENTS USING CALIPER AND 3D LASER SCANNING: PRELIMINARY RESULTS

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Abstract

Measurements and different analyses of dental casts are essential for precise diagnosis of an orthodontic case. At present, virtual computerized models, such as from Laser Scanning, are available for clinicians, supplemented by dedicated software for performing the required measurement. The purpose of this study is to measure and compare a set of dental casts using calipers and Laser Scanning. Impressions were taken from the patients, providing 9 dental cast and 9 virtual (laser scanning) models. Measurements of arc width and arc perimeter were made on both, while measurements of palatal length and palatal depth were difficult to obtain using calipers but can be done on the computerized models (using RapidForm software). Some preliminary results are shown to illustrate this approach. For the tested clinically applicable methods, measurement with digital calipers on dental cast can give the best accuracy but in certain case this method cannot be used accurately such as palatal depth and palatal length. However, computerized (Laser Scanning) models accuracy is clinically acceptable. In the near future, the 3D virtual model would become the standard tool for orthodontic clinical practice.

1.0 INTRODUCTION

Successful orthodontic treatment is based on comprehensive diagnosis and treatment planning. A few of the fundamental factors in the diagnosis are the spacing condition, tooth size, arch form and its dimensions, the tooth-arch discrepancies, palatal depth and palatal length. The model analysis is a time-consuming procedure. Nevertheless, it is a vital part in the diagnosis and subsequent treatment planning process. However, in a day-to-day practice many orthodontists judge the models subjectively, without applying analytical tests.

Traditionally, measurements on dental casts are performed with the aid of either Vernier calipers or needle pointed dividers. By using these methods, a clinically significant measurement error (>1.5 mm) can occur. The measurement of palatal depth and palatal length cannot be done by using these methods. These measurements are important to orthodontist to diagnose, plan and execute treatment in each patient. Alternatively, measurements on photocopies, photos, holograms, or digitization of points from the casts had been proposed, but these methods demonstrated errors as well.

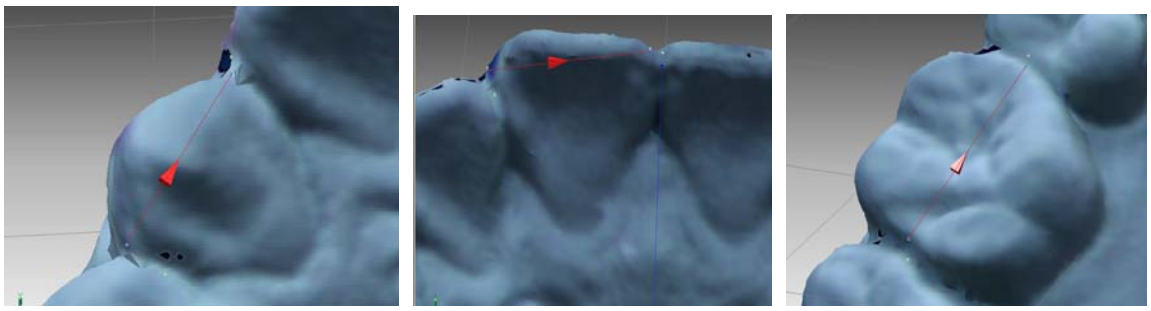
Different factors may influence the accuracy and reproducibility of measurements of individual teeth within the dental arch. Among these factors are the existing spacing condition, the inclination of the teeth, rotations, presence of interproximal contacts and anatomical variations. Because the need for evidence-based orthodontics is increasing, the accuracy and reproducibility of different measurement methods ought to be evaluated. Otherwise, clinical decisions cannot be justified scientifically.

With the ultimate aim of a ‘paperless' orthodontic office, the need for replacement of the plaster casts has emerged. Thus, attempts to develop a computerized study model database and analysis have been made. Laser Scanning is such the new alternative in imaging method for creating 3D computerized models using a laser beam on a cast. These computerized models are the platform for calculating distances by using designated software and estimating treatment effects and tooth movements in this way. Polygon Editing Tools (PET) is such a system that is commercially available and provides the possibility of transforming impressions or plaster casts into 3D virtual models.

2.0 LASER SCANNING FOR 3D DENTAL CAST MODEL

In recent years, modeling and measurement of the dental cast is becoming more important for orthodontic clinical use. In orthodontic treatment, a wealth of information obtained from dental casts plays a significant role in diagnosis, treatment planning, and evaluation. Recently, a more accurate quantification of dental cast information has become possible as a result of advances in the application of three-dimensional (3-D) measuring devices to dentistry. Motohashi and Kuroda simulated orthognathic surgery on digital images based on 3-D information from dental casts. Furthermore, Yamamoto et al evaluated the distal driving behavior of the canine using 3-D information.

Three-dimensional digital imaging will have a major impact on clinical dentistry in the near future. Interactive three-dimensional images of the soft and hard tissues of dental patients (Virtual Dental Patients) will provide quantitative evidence to aid dentists in diagnosis, treatment planning, and outcome assessment. Before this can occur, however, these images must be shown to be accurate representations of the patients. This study is a first step in measuring image accuracy by creating 3D computer models of simulated dental arches.



(a) (b) (c)

FIGURE 1 : Measurements of mesiodistal width of (a) canine (b) incisor (c) premolar using the RapidForm 2004, as shown from different views.

3.0 MATERIALS AND METHOD

There are 4 steps involve in creating three-dimensional computer images of dental casts as follows :

1) Make dental impressions of the tissues
2) Make stone casts from the impressions
3) Scan the casts
4) Process the scan data

The first step is a clinical procedure and the other three steps are laboratory procedures.

Close range measurement method is used for laser scanning data capture. 3D Laser Scanning is a laser range scanning devices based on light interferometry that provides a much more automatic tool for obtaining a digital model of an existing 3D object (Alvin et al, 2002). The scanner is also useful for capturing the 3D shape of physical objects, especially those with complex geometries and free-form surfaces.

In this study, the dental cast was put on the rotating table (which was rotating in 360° with 6 time capture of scanned image at every 60° in different viewed). Two laser scanners (Figure 1) were used to capture scanned data using Polygon Editing Tools (PET) software. The scanning was performed using VIVID 910 (3D scanner operating on laser-light stripe triangulation range finder principle) and the distance of the dental cast from the scanner was about 0.7 meter.

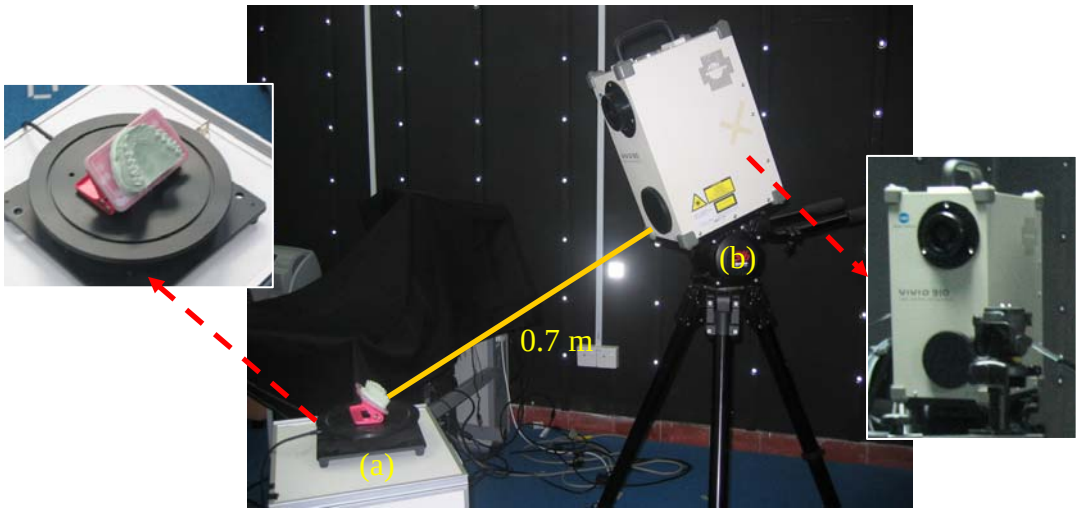


FIGURE 2 : The position of taking laser image of dental cast using (a) rotating table (360°) and (b) VIVID 910 (laser scanner)

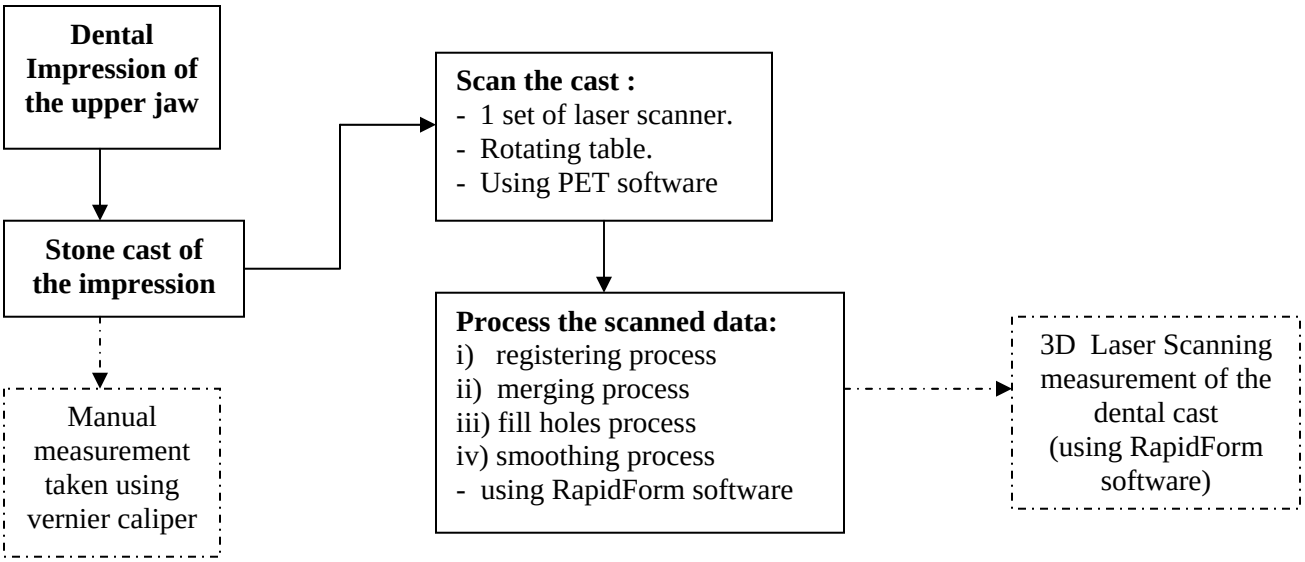


FIGURE 3 : The flowchart to get the measurements

The widths of every tooth in the upper arch (14 teeth for each person) were examined. The same investigator performed tooth size measurements of mesiodistal width in the following manner.

i) On the plaster models, using the same vernier caliper.

ii) On the computerized models, using the RapidForm 2004 measurements tools.

Measurements of arc width were performed on the plaster model and on the computerized models. Only upper sets of teeth were measured (Figure 4).

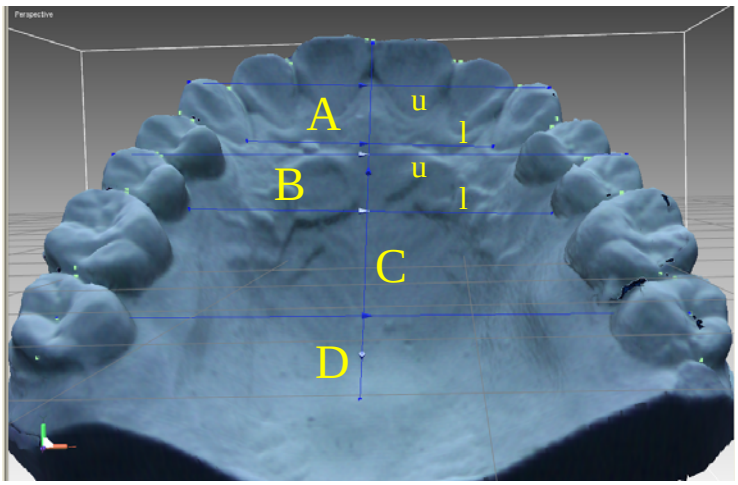


FIGURE 4 : Front view of the measurements of (A) intercanine (B) interpremolar (C) palatal length (D) palatal depth distances using the RapidForm 2004 tool. The upper (u) measurements are made between the tip of the cusps, and the lower (l) between the gingival margins of the teeth.

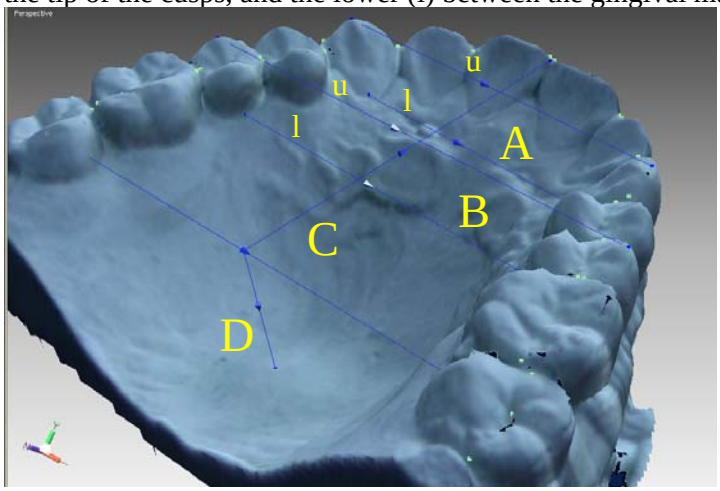


FIGURE 5 : Side view of the measurements of (A) intercanine (B) interpremolar (C) palatal length (D) palatal depth distances using the RapidForm 2004 tool. The upper (u) measurements are made between the tip of the cusps, and the lower (l) between the gingival margins of the teeth.

The scanned data was imported to RapidForm (a professional 3D reverse engineering) software for data processing. The steps to process the scanned data are registering, merging, fill holes and smoothing (Figure 2). Registration allows plotting of multiple point clouds or polygonal shells using overlapping regions. Secondly, the shells that have been aligned by registration process are merged into one united shell. During the merging process, overlapped regions between shells are removed and neighboring boundaries are stitched together with newly added polygons. The results and accuracy of shells are still maintained after merging. The fill holes operation fills holes in a model that may have been introduced during the scanning process. The operation constructs a polygonal structure to fill the hole, and both the hole and the surrounding region are remeshed so the polygonal layout is organized and continuous. Sometimes scanned data may have too much bump and detail of surface roughness in the scanning process. By smoothing the polygon model, it can reduce this roughness.

4.0 RESULTS

There were 15 measurements were done in this study (Table 1). Each measurements were have 3 times of measured. These is because to get the high precise value of measurements. There were two methods were done in this study. Method one is by taking the dental cast measurements using laser scanner while the other method is by taking the measurements of the dental casts using vernier caliper. When the measurements were compared between the two methods, all measurements were highly correlated (tooth width and tooth dimension). In this study, the main focus was to measure the palatal depth and palatal length of the model which cannot be obtain using manual measurement (using vernier calipers). The result showed that palatal depth and palatal length of the model can be easily derived using RapidForm 2004 software.

Rapidform Measurement for Dental Cast (mm)											
UPPER TEETH	**A015720**	**A097788**	**A927716**	**B191064**	**B220610**	**B239943**	**B266985**	**ELIAS**	**B268156**	**AVG**	**STD**
molar2_width	54.3180	58.0200	63.2740	58.2010	51.6690	50.8410	55.5910	57.9800	51.2450	**55.6821**	**4.1205**
dimesion_molar2L	8.1300	8.7810	9.9610	10.5790	9.4560	10.6270	10.1780	9.5930	9.5950	**9.6556**	**0.8141**
dimension_molar1L	9.2680	10.2270	10.0300	11.0740	9.4470	10.0650	10.8090	10.8430	10.7230	**10.2762**	**0.6377**
dimension_premolar2L	5.9850	6.4730	7.3450	6.9680	6.7840	6.9400	6.5120	6.8440	6.9280	**6.7532**	**0.3869**
dimension_premolar1L	5.6470	6.2470	7.5360	7.0690	6.2090	7.4090	7.2260	7.8160	7.8550	**7.0016**	**0.7851**
dimension_canine	6.6600	6.7910	8.0510	8.0090	6.3650	7.0260	7.6820	7.7760	8.5310	**7.4323**	**0.7429**
dimension_lateralInsizerL	6.7060	7.6840	6.5180	7.4960	6.3770	7.1590	6.8870	7.5340	7.3440	**7.0783**	**0.4753**
dimension_centralInsizerL	8.4340	9.3170	8.8780	9.3010	6.4080	7.9280	8.3250	9.0520	8.8790	**8.5024**	**0.9110**
dimension_molar2R	8.3970	9.2330	10.0860	11.4410	9.3640	9.4190	8.1440	9.7320	10.1600	**9.5529**	**0.9828**
dimension_molar1R	8.8230	10.1340	11.0770	11.0810	8.6550	10.5080	10.9500	9.2870	10.9620	**10.1641**	**0.9933**
dimension_premolar2R	6.1750	6.1920	7.0870	6.6960	6.5250	6.6980	6.6150	8.0030	6.6920	**6.7426**	**0.5481**
dimension_premolar1R	6.2110	6.6780	7.7220	6.9670	6.8970	7.1320	7.4380	7.7980	7.5790	**7.1580**	**0.5263**
dimension_canineR	6.9090	7.8390	7.8090	7.8840	6.8810	7.1550	7.4190	8.3090	8.0210	**7.5807**	**0.5103**
dimension_lateralInsizerR	6.5380	7.5420	6.2540	6.7640	6.9740	7.4830	7.0030	7.4920	8.0100	**7.1178**	**0.5580**
dimension_centralInsizerR	8.0290	9.2030	9.1500	8.8800	6.8060	8.6840	9.5440	9.0230	9.6400	**8.7732**	**0.8788**
									TOTAL	**11.2981**	**12.0303**

Table 1 : The measurements of dental cast using RapidForm 2004 software.

Caliper Measurement for Dental Cast (mm)											
UPPER	**A015720**	**A097788**	**A927716**	**B191064**	**B220610**	**B239943**	**B266985**	**Elias**	**B268156**	**AVG**	**STD**
molar2_width	53.6500	56.5000	62.0500	57.1500	50.6500	50.2000	54.9000	57.4500	51.3500	54.8778	3.8659
dimesion_molar2L	7.8000	8.0000	9.8500	10.0500	9.2000	9.2500	9.3000	10.0500	11.5500	9.4500	1.1314
dimension_molar1L	8.6500	10.0000	10.0500	11.4500	9.0000	10.0500	10.2000	11.1000	11.1000	10.1778	0.9424
dimension_premolar2L	6.1000	6.1000	6.6500	6.1500	6.2000	6.9000	6.7000	6.7500	6.6000	6.4611	0.3190
dimension_premolar1L	5.9000	5.9500	7.1500	6.6000	6.2500	6.6000	6.8000	7.2500	7.5000	6.6667	0.5668
dimension_canine	6.6000	7.3500	7.7500	8.0500	6.2000	7.6000	7.0000	8.3000	8.4500	7.4778	0.7653
dimension_lateralInsizerL	6.1000	7.2000	6.6500	7.4500	6.1500	6.6000	6.6000	7.3000	7.5000	6.8389	0.5390
dimension_centralInsizerL	7.4500	8.7500	8.0500	8.9000	6.0000	7.5000	8.1000	8.7500	9.0000	8.0556	0.9665
dimension_molar2R	8.0000	8.5000	9.1500	10.6000	9.3000	9.0000	5.0000	9.2000	10.5000	8.8056	1.6535
dimension_molar1R	9.1000	10.3500	10.3500	11.3500	8.9000	13.0000	19.0000	10.1000	11.3500	11.5000	3.0755
dimension_premolar2R	6.2000	6.0500	6.7500	6.6000	6.2500	6.4000	6.5000	7.9500	6.5500	6.5833	0.5568
dimension_premolar1R	6.1000	6.1000	7.0500	6.8500	6.3500	5.9500	7.4000	7.2500	7.2500	6.7000	0.5750
dimension_canineR	5.8500	7.6500	7.6000	7.7500	6.9500	7.5500	6.9000	8.1500	8.4500	7.4278	0.7714
dimension_lateralInsizerR	5.6500	6.9000	9.6500	7.2000	6.5000	6.8000	7.1500	7.5500	8.0000	7.2667	1.1107
dimension_centralInsizerR	7.5500	8.2000	8.6000	8.6000	6.3000	7.7000	8.5500	9.0500	9.0000	8.1722	0.8718
									TOTAL	**11.0974**	**11.9175**

Table 2 : The measurements of dental cast using Caliper

DIFFERENT VALUE OF RAPIDFORM VS CALIPER (mm)											
UPPER	**A015720**	**A097788**	**A927716**	**B191064**	**B220610**	**B239943**	**B266985**	**Elias**	**B268156**	**AVG**	**STD**
molar2_width	0.6680	1.5200	1.2240	1.0510	1.0190	0.6410	0.6910	0.5300	-0.1050	0.8043	0.4684
dimesion_molar2L	0.3300	0.7810	0.1110	0.5290	0.2560	1.3770	0.8780	-0.4570	-1.9550	0.2056	0.9614
dimension_molar1L	0.6180	0.2270	-0.0200	-0.3760	0.4470	0.0150	0.6090	-0.2570	-0.3770	0.0984	0.3980
dimension_premolar2L	-0.1150	0.3730	0.6950	0.8180	0.5840	0.0400	-0.1880	0.0940	0.3280	0.2921	0.3590
dimension_premolar1L	-0.2530	0.2970	0.3860	0.4690	-0.0410	0.8090	0.4260	0.5660	0.3550	0.3349	0.3154
dimension_canine	0.0600	-0.5590	0.3010	-0.0410	0.1650	-0.5740	0.6820	-0.5240	0.0810	-0.0454	0.4320
dimension_lateralInsizerL	0.6060	0.4840	-0.1320	0.0460	0.2270	0.5590	0.2870	0.2340	-0.1560	0.2394	0.2807
dimension_centralInsizerL	0.9840	0.5670	0.8280	0.4010	0.4080	0.4280	0.2250	0.3020	-0.1210	0.4469	0.3250
dimension_molar2R	0.3970	0.7330	0.9360	0.8410	0.0640	0.4190	3.1440	0.5320	-0.3400	0.7473	0.9820
dimension_molar1R	-0.2770	-0.2160	0.7270	-0.2690	-0.2450	-2.4920	-8.0500	-0.8130	-0.3880	-1.3359	2.6586
dimension_premolar2R	-0.0250	0.1420	0.3370	0.0960	0.2750	0.2980	0.1150	0.0530	0.1420	0.1592	0.1204
dimension_premolar1R	0.1110	0.5780	0.6720	0.1170	0.5470	1.1820	0.0380	0.5480	0.3290	0.4580	0.3588
dimension_canineR	1.0590	0.1890	0.2090	0.1340	-0.0690	-0.3950	0.5190	0.1590	-0.4290	0.1529	0.4539
dimension_lateralInsizerR	0.8880	0.6420	-3.3960	-0.4360	0.4740	0.6830	-0.1470	-0.0580	0.0100	-0.1489	1.2962
dimension_centralInsizerR	0.4790	1.0030	0.5500	0.2800	0.5060	0.9840	0.9940	-0.0270	0.6400	0.6010	0.3515
									TOTAL	**0.2007**	**0.9794**

Table 3 : The differentiation values between Rapidform and Caliper

When the data were compared between the two methods, all measurements were highly correlated. The tables above show that the different value of standard deviation between RapidForm and Caliper is about 0.1128 mm (12.0303 – 11.9175). Table 3 shows that the average value of different value between RapidForm and caliper is 0.2007 with a standard deviation are 0.9794.

5.0 DISCUSSION

A statistical hypothesis is a claim or statement about statistical properties of population. A hypothesis testing is a standard procedure for testing a statistical hypothesis. The testing of statistical hypothesis is perhaps the most important area in decision theory. The test statistic is a value computed from sample data. The test statistic is used to determine whether there is significant evidence against the null hypothesis. Thus, it is used in making the decision whether or not to reject the null hypothesis. The test statistic formula is:

$$z = \frac{\overline{x} - \mu_0}{\sigma / \sqrt{n}}$$

Measurements made directly on cast with caliper were found to be the most accurate and repeatable. Nevertheless, RapidForm 2004 showed good result as well (Table 1). By using test statistic the result of the sample data using RapidForm is accepted. The z value of rapidForm sample data is equal to 0.0500 which is in the range of 95% confidence level. These mean that all measurements done using RapidForm were acceptable.

The digital system seems as to be a very attractive clinical solution, as because it has the advantage of storing cast models information in an electronic format, which would benefit the orthodontist from both the clinical management and data storage perspectives. In order for a program to be accepted by orthodontists, it has to be accurate and clinically efficient, user friendly and economic time for their operation. On the other hand, for research purposes and forensic investigations, the requirements are different and the accuracy of the method is much demandlier. When evaluating the accuracy of 3D Laser Scanning techniques, it seems that it is still inferior to the conventional method of cast measurements using digital calipers. It may also be less accurate when compared to measurements performed with the use of an optical or laser beam. Therefore the examined 3-D virtual models seem appropriate as a clinical tool, but inferior as a research tool.

6.0 CONCLUSION

Considering this to be a valid method, for evaluating tooth measurements on the setups, the conclusions can be described as follows:

- Measurement with digital calipers on plaster models produced the most accurate and reproducible results but not suitable for some measurements (palatal depth & palatal length).

- The RapidForm measurement tool showed high accuracy and reproducibility but was inferior to measurements done on plaster models with digital calipers.

- Digital calipers seem to be a more suitable instrument for scientific work. However, 3D Laser Scanning accuracy is clinically acceptable, and it is likely, taking into consideration its present advantages and future possibilities, that the examined or an equivalent 3D virtual model procedure would become the day-to-day standard for orthodontic use.

7.0 ACKNOWLEDGMENT

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