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Assessment of Accuracy and Reliabilty of Measurements Obtained on 3D Scanned Models to Conventional Models

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***Abstract*---**Aims and Objectives: To conclude on superior method of model fabrication and compare accuracy and the reliability of measurements obtained on 3D scanned models to conventional models. Materials and Methods: A total of 20 orthodontic study models were obtained from the department of orthodontics and dentofacial orthopaedics with a full set of permanent teeth from the right first molar to the left first molar and no anomalies of the crown. The plaster models were measured to the nearest 0.01 mm using the Aerospace Electronic Digital Caliper. Identical plaster models were scanned by placing each arch on the integrated rotary table (dental wings 3SERIES) .The acquired data was then processed and exported in stereo lithographic format using DWOS CAD/CAM software. Digital casts were later measured to the nearest 0.123 mm using 3D-Tool 64-Bit Free Viewer V13. Results: indicated that all measurements for the arch and tooth size measurements for both methods were highly correlated (r . 0.99; P\0.05).Cronbach α value of the data at T1 and T2

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from incisal segment ,canine segment and the molar segment measured using the two methods was very close to the ideal value of 1, indicating high intraobserver reliability.

***Keywords*---**3D models, light scanner, measurements, non-contact structured, plaster models.

Introduction

In dentistry, plaster models are used to analyze the occlusion and aid in treatment planning. Linear measurements made on plaster models are commonly used for space, tooth size, and arch width analyses (1). Direct measurement of casts using calipers has been accepted as the clinical standard for linear measurements. The advent of 3-dimensional (3D) image models has spurred a growing interest in their usefulness to address the issues of limited storage space and transport as well as to prevent the long-term wear and tear of the study models that is commonly seen with stone or plaster models. Several studies have investigated digital models made by systems that require models or impressions to be couriered to the proprietors such as OrthoCAD (2,3), DigiModel (4) for their clinical acceptability compared with conventional plaster models. OrthoCAD models are scanned by a patented “destructive scanning” technique, whereas DigiModel and emodel use cone-beam computed tomography (CBCT)-based and laser-based scanners, respectively (3,4). Measurements on these systems have been extensively compared with digital calipers and have been found to be clinically acceptable.These computerized models are the platform for calculating distances by using designated software and estimating treatment effects and tooth movements in this way.

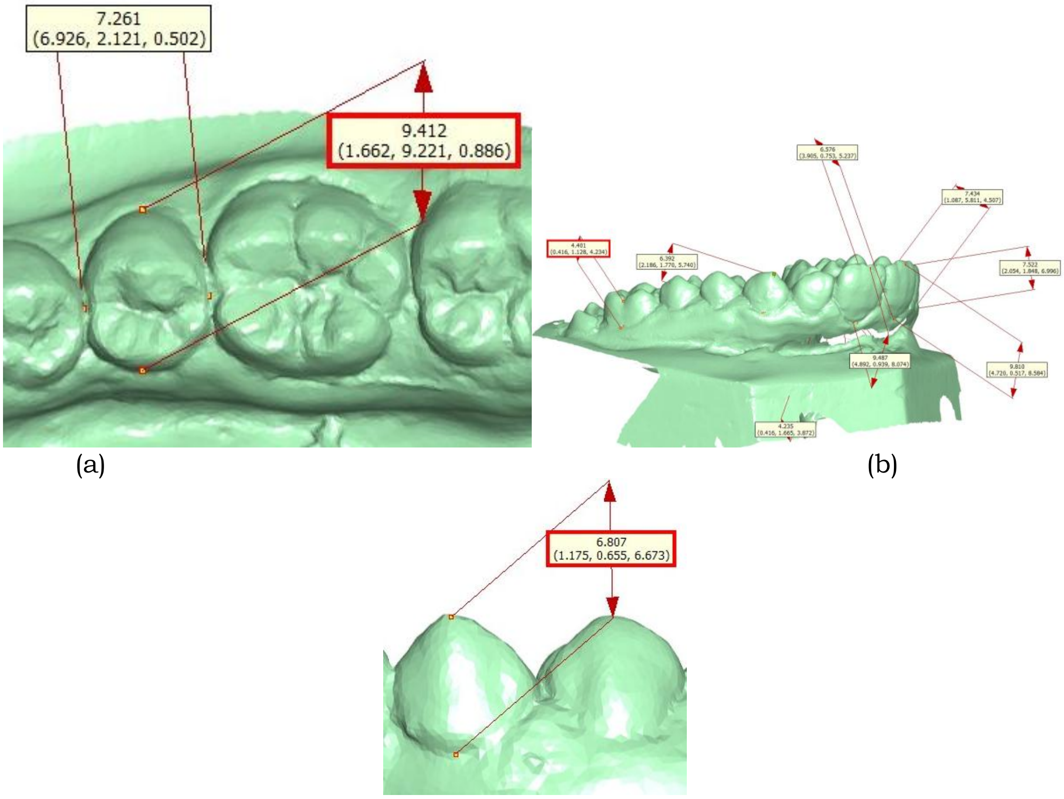
The structured-light scanner is a type of noncontact active scanner that reconstructs 3D surfaces based on triangulation. The active projector device emits a structured-light pattern that forms an illusion of texture on an object. This increases the number of unique definitions of matchable object points, corresponding to every unitary position in the image, thus enabling 3D object reconstruction by matching of the projected and recorded patterns (5). As with any new method, clinical acceptance must be assessed by comparing it with the old method or the current gold standard as in this case, measurements made manually on plaster models. Therefore, the purpose of this study was to evaluate the agreement of linear measurements made on 3D models scanned using a structured light projector scanner and software (DWOS SERIES 3) with those made on plaster models with digital calipers.

Materials and Method

A total of 20 orthodontic study models were obtained from the department of orthodontics and dentofacial orthopaedics. The inclusion criteria were a full set of permanent teeth from the right first molar to the left first molar with no anomalies of the crown.The plaster models were measured to the nearest 0.01 mm using the Aerospace Electronic Digital Caliper (figure1). Identical plaster models were scanned by placing each arch on the integrated rotary table (dental wings 3SERIES) .The acquired data was then processed and exported in stereo lithographic format using DWOS CAD/CAM software (figure 2). Digital casts were later measured to the nearest 0.123 mm using 3D-Tool 64-Bit Free Viewer V (13).

Figure 1. Measurements taken on plaster model using digital caliper

Figure 2: dental wings 3SERIES intraoral scanner



(a) (b)

(c)

Figure 3. Tooth dimensions were measured in 3D perpendicular planes :(a) the greatest mesiodistal widths;(b) the greatest buccolingual or bucco-palatal widths and (c) the cervicoincisal axis of the clinical crowns of each tooth from incisal segment ,canine segment and the molar segment were measured.

Arch measurements included were interpremolar width(At buccal cusp tips;At distal pit;At lingual cusp tips) and intermolar width(At mesiolingual cusp tip;At central fossa ;At distobuccal cusp tip)

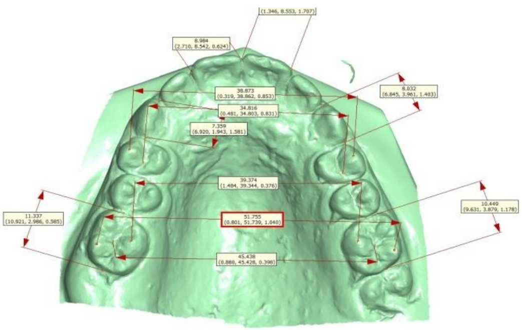


Figure 4. Arch dimensions

Statistical analysis

- In this study, we compared the linear measurements made in clinically relevant directions (arch measurements, mesiodistal widths, buccolingual widths and cervicoincisal axis of the clinical crowns) between the two methods which was subjected to statistical analysis.
- Student t- test was applied to make the comparison.
- The Pearson correlation was used to estimate the strength of the linear relationship between each digital model measurement and the stone cast measurements.
- The accuracy and repeatability (intra-observer reliability) of measurements obtained using the digital and plaster models were evaluated with Cronbach α.

Results

- Intraoperator and interoperator calibrations indicated that all measurements for the arch and tooth size measurements for both methods were highly correlated (r. 0.99; P\0.05) as analyzed using the Pearson correlation coefficient.
- Cronbach α value of the data at T1 and T2 from incisal segment ,canine segment and the molar segment measured using the two methods was very close to the ideal value of 1, indicating high intraobserver reliability.

Table 1
Coefficients for mesiodistal measurements made by the digital caliper and 3D software methods

Mesiodistal	3d software		Digital Caliper		Difference		Correlation coefficient	P value	Cronbach's Alpha
	Mean	SD	Mean	SD	Mean	SD			
Molars	10.793	0.651	10.614	0.603	0.179	0.455	0.740	<0.001**	0.849
Canine	7.484	0.901	7.396	0.714	0.089	0.571	0.773	<0.001**	0.859
Incisors	7.175	1.638	7.166	1.650	0.009	0.448	0.963	<0.001**	0.981

Table 2
Coefficients for buccolingual measurements made by the digital caliper and 3D software methods

Buccolingual	3d software		Digital Caliper		Difference		Correlation coefficient	P value	Cronbach's Alpha
	Mean	SD	Mean	SD	Mean	SD			
Molars	11.122	0.726	11.110	0.621	0.012	0.402	0.833	<0.001**	0.903
Canine	7.141	1.000	7.332	0.991	-0.191	0.599	0.819	<0.001**	0.900
Incisors	6.786	0.759	6.786	0.803	-0.000	0.217	0.963	<0.001**	0.980

Table 3
Coefficients for cervicoincisal measurements made by the digital caliper and 3D software methods

Cervicoincisal	3d software		Digital Caliper		Difference		Correlation coefficient	P value	Cronbach's Alpha
	Mean	SD	Mean	SD	Mean	SD			
Molars	4.529	0.885	4.528	0.861	0.001	0.407	0.892	<0.001**	0.943
Canine	7.641	0.868	7.817	0.982	-0.176	0.292	0.958	<0.001**	0.975
Incisors	8.336	1.220	8.324	1.228	0.012	0.669	0.851	<0.001**	0.919

Table 4
Coefficients for interpremolar measurements made by the digital caliper and 3D software methods

Interpremolar	3d software		Digital Caliper		Difference		Correlation coefficient	P value	Cronbach's Alpha
	Mean	SD	Mean	SD	Mean	SD			
Buccal Cusp Tip	37.423	5.748	37.973	5.408	-0.549	0.770	0.992	<0.001**	0.995
Distal Pit	34.369	4.647	33.668	4.745	0.702	0.948	0.980	<0.001**	0.990
Lingual Cusp	29.803	4.040	29.625	4.070	0.178	0.632	0.988	<0.001**	0.994

Table 5
Coefficients for intermolar measurements made by the digital caliper and 3D software methods

Intermolar	3d software		Digital Caliper		Difference		Correlation coefficient	P value	Cronbach's Alpha
	Mean	SD	Mean	SD	Mean	SD			
Mesiolingual Cusp	37.431	4.202	37.457	4.278	-0.026	0.534	0.992	<0.001**	0.996
Central Fossa	43.377	5.024	42.806	5.277	0.571	0.532	0.996	<0.001**	0.997
Distobuccal Cusp	50.921	4.603	50.784	4.741	0.137	0.606	0.992	<0.001**	0.996

Discussion

The noncontact structured-light scanner Dwos series 3 provides an indirect method to obtain digital models by scanning from plaster models. Principally, the structured-light scanner emits structured illumination onto the object to be scanned and reconstructs the spatial location of the corresponding points of the object's surface based on calculations made from the reflected patterns of the points or lines received by the sensor (5). The compact 3D system is embedded with a powerful computer and offered in a flexible CAD configuration. Designed to evolve with a laboratory's growing needs, it's an affordable solution to which additional DWOS applications can be added at any time.Structured-light scanners, such as the Comet 100 optical digitizer, are also commercially available but a previous study focused on measuring simulated dental objects on arches rather than on clinically relevant study models (6).

Metzler et al 7 found no significant differences between direct measurements and indirect measurements made using the software on images scanned with the 3D VECTRA scanner(Canfield Scientific). Similar direct measurements could not be made with this type of noncontact surface scanner because the digital model produced would not show pencil markings for direct comparisons to be made. When choosing to adopt a new system, it is ideal to consider that the available systems are easily accessible, highly accurate, highly repeatable or reproducible, viewable in any direction to allow measurements of casts separately and in occlusion. On the other hand, assessing the reproducibility or repeatability of the methods and the agreement between the old and new methods, may be necessary from a statistical point of view. Repeatability, or reproducibility, is the precision of the closeness of each successive measurement for the same object (8).

For this study, we used 2 methods for assessing precision and agreement, coefficient of intraclass reliability (Cronbach α) and pearson correlation coefficient. Intraoperator calibrations indicated that all measurements for the arch and tooth size measurements for both methods were highly correlated ($P<0.05$) as analyzed using the Pearson correlation coefficient. The results of this study support the validity and reliability of measurements calculated using 3D models. There were no statistically significant differences in measurements taken using digital and plaster models of the same patient. Similar to our findings,Chee Seng Chan et al. found no significant difference when comparing the reliability of tooth size measurements obtained using plaster and digital models (9).

Conclusion

- There is considerable agreement between linear measurements of clinically relevant arch and tooth size on the orthodontic study models using these two methods.
- Measurements made from the 3D image models appear generally to be as precise as measurements made on plaster models. Therefore, this study suggests that the plaster cast method and the 3D measurement method can be used interchangeably

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