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Validity and reliability of measurements of the parameters of smile aesthetics: a comparison between digital and plaster models

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Abstract

This study aims to evaluate the validity and reliability of the Digital models derived from LED scanner and CBCT (Cone Beam Computed Tomography) in measuring parameters of smile aesthetics compared with measurements on plaster casts. The study sample comprised plaster casts and digital models obtained from 10 subjects. Height (H), mesiodistal diameter (MDD) of the anterior teeth were measured with a digital calliper on the plaster models and with the orthodontic software (Meshlab) on the digital models. Validity was assessed using paired t-test and the reliability of measurements was evaluated with the Intra-class Correlation Coefficient (ICC). There was statistically significant differences observed between the measurements made with the two methods. Linear measurements made on digital model although clinically acceptable but does not meet the Gold standard (plaster model) accuracy.

Keywords: Smile Aesthetics, Plaster models, Digital models, Validity, Reliablity

Introduction

Successful treatment requires comprehensive diagnosis and treatment planning. Evaluation and analysis of photographic records and study models is fundamental. Plaster study models are represented as the gold standard in the reproduction of dental arches. In 19th century scanning systems was developed and introduced into the dental practice systems for digitizing plaster impressions as well as systems for digital acquisition of dental arches with intraoral scanners which is direct scanning technique (1), LED scanner, Laser scanner are indirect scanning techniques. Before Scanners CBCT was the most accepted diagnostic digital tool comes under direct method. Plaster study models are acceptably reliable for a complete evaluation of the patient's occlusion, symmetry of the dental arches and palate, position of teeth and their dimension, studying the curve of Spee and Wilson curves, overbite, overjet and Bolton analysis (2,3). The disadvantages using plaster models include physical storage, risk of damage, fractures, or inaccuracies such as air bubbles, high weight, difficult communication with patients and colleagues, difficulty accessing to the model from many locations. Intraoral 3D scanned models are at ease to store and transfer, have no risk of physical damage, and are available to discuss treatment with the patient during the record taking visit (4–7).

Moreover, the traditional impression tray, inaccurate impression dimensions, too much or little impression material, inappropriate adhesion of the impression to the impression tray, and impression disinfection procedure can be responsible for inaccuracies with errors in the plaster model (8). On the other hand, digital models of the jaws do not require disposal, nor do they require the packaging and transportation that the impression materials and plaster models do; for these reasons, it is both more economical and ecological technique.

Various Digital systems have been introduced in clinical dental practice as a replacement for the dental impression-taking or preserving procedure. An LED scanner is easy to use and generates stereolithography (STL) files that can be used to make digital models. Today new scanners as intraoral scanners are small in size, produce fast image creation and no pre-scan dust is required on dental elements. These upgrading features lead to greater patient acceptance and also has reduced the clinician's working time. But main drawback is the setup has a higher cost comparing other scanners.

In orthodontics, the treatment plan formulated aims to restore the occlusion, the correct ratio between upper and lower jaw for chewing function and, in particular, the aesthetics of teeth and soft tissue. The main objective of aesthetic dental treatment is to obtain a beautiful smile, which is an integral part of the individual’s appearance.

Today's society develops around the digital world and are conveyed daily through selfies, photos or videos. Therefore, both the clinician and layperson are aware of the role of smile and aesthetics. This requires careful evaluation of the dental and gingival parameters to enhance the aesthetics of the smile. For establishing a better treatment plan, it is just not enough to recognize what interferes with the smile, but a diagnosis must be made using parameters to establish what is not normal and must be corrected.

Methods

Study Sample

The study sample comprised plaster casts and digital models obtained from 10 subjects randomly selected amongst those who underwent dental visit located in Bharti Vidyapeeth dental college and hospital sangli. All the subjects were voluntarily participated and provided informed consent. 10 sets of plaster casts and 10 sets of LED scan derived digital models and 10 sets of CBCT models were available for the study; each enrolled set of the model included a plaster model and a digital model including CBCT and LED scanned models derived from the same subject. The sample size selected was on the basis of previous studies with digital and plaster models used a similar sample size (5, 12–15).

The traditional Alginate impression was made with an commercial impression trays.

All impressions were cast in conventional material (OrthoKal stone). Then the same cast was scanned in LED scanner and Direct scanning of same patient was undertaken in CBCT machine.

Both the plaster model and the digital model were performed by the same operator during a single session.

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The inclusion criteria of subjects included both male as well as female; age between 18 and 40 years; permanent dentition from first molar to first molar; all teeth except carious lesions, or crown defects that might affect the mesiodistal morphology of the crown. The exclusion criteria included as Angle's Class II and Class III malocclusion, severe crowding, anterior cross-bite, gingival recession, presence of fixed restorations, and heavily restored teeth. The dental casts enrolled did not present any positive or negative bubbles, missing tooth material or breakage.

Data collection

The following measurements were made: mesiodistal diameter (MDD) of crown of the upper central, lateral incisors and canine taken at the maximum convexity of the mesial and distal surfaces; height (H) of the upper central, lateral incisors and canine measured from the incisal edge to the gingival zenith; connecting space (CS) between upper right/left central and lateral incisor and upper right/left canine. The space between gingival papillary tip and incisal tip (the orange point in Figure 1and 2) and contact point between tooth (the Orange point in Fig.3 and 4) is called connecting space(9). All plaster measurements were made with an electronic digital calliper with the nearest 0.01mm, from the frontal view to provide better visibility. To evaluate the contact point the model can be rotated to the occlusal view.

The 3D LED scan visible on the PC is transferred in STL format to MESH Lab software to make measurements digitally on the digital model. As in the plaster model, measurements are made in frontal view. The manipulation of the digital model is allowed though image handler methods. The program can also be zoomed, rotated and panning features also is fully exploited. The measurements of H and CS was made parallel with the buccal surfaces; the MDD measurements were made parallel to the occlusal surfaces. All recordings made was nearest to 0.01 mm.

Validity and Reliablity was considered as the extent to which the new diagnostic test (digital model) measured against the gold standard (dental cast) (15).

Results

Statistical procedures

- Data obtained was compiled on a MS Office Excel Sheet (v 2019, Microsoft Redmond Campus, Redmond, Washington, United States).
- Data was subjected to statistical analysis using Statistical package for social sciences (SPSS v 26.0, IBM).
- Descriptive statistics like Mean & SD for numerical data has been depicted.

✓ Inter group comparison (>2 groups) was done using one way ANOVA followed by pair wise comparison using post hoc test.

✓ Intra class correlation & Cronbach's alpha test was used to find out reliability & consistency of readings between the 3 techniques

✓ Dalhbergs formula was used to have a direct comparison of error sizes between measurements with different units or between measurements with different means.

For all the statistical tests, $p<0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power to the study as 80%.

* = statistically significant difference ($p<0.05$)

** = statistically highly significant difference ($p<0.01$)

= non significant difference ($p>0.05$) … **for all tables**

The Inter technique comparison of values between each pair of group using Tukey's Post Hoc Tests(Table No.1)

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There was a statistically highly significant / significant difference seen for the values between the groups (p<0.01, 0.05) of Plaster models, LED scanner and CBCT derived digital model. The variation or difference was seen for:

Rt central ht between the groups 1 vs 3, 2 vs 3

Rt Lateral ht between the groups 1 vs 3, 2 vs 3

Rt Canine ht between the groups 1 vs 3, 2 vs 3

Lt Central ht between the groups 1 vs 3, 2 vs 3

Lt Lateral ht between the groups 1 vs 3, 2 vs 3

Rt central width between the groups 2 vs 3

The Reliablity statistics states that (Table:2) There was a statistically significant / highly significant reliability for Rt central ht, Lt Canine ht & Lt Lateral width between the 3 techniques (p<0.01, 0.05) with Cronbach's Alpha >0.60 and average ICC value > 0.668

However since single measures ICC values are less than 0.7 it is concluded that there was a poor to moderate agreement between the 3 techniques.

Dependent Variable	(I) group	(J) group	The Inter technique comparison of values between each pair of group using Tukey's Post Hoc - Table 1			95% Confidence Interval	
			Mean Difference (I-J)	Std. Error	p value	Lower Bound	Upper Bound
Rt central ht	1	2	-.2400000	.2980277	.703#	-.978935	.498935
	1	3	-2.0750000*	.2980277	.000**	-2.813935	-1.336065
	2	3	-1.8350000*	.2980277	.000**	-2.573935	-1.096065
Rt Lateral ht	1	2	-.1480000	.3373406	.900#	-.984408	.688408
	1	3	-1.6350000*	.3373406	.000**	-2.471408	-.798592
	2	3	-1.4870000*	.3373406	.000**	-2.323408	-.650592
Rt Canine ht	1	2	-.2340000	.4184511	.843#	-1.271515	.803515
	1	3	-1.3300000*	.4184511	.010*	-2.367515	-.292485
	2	3	-1.0960000*	.4184511	.037*	-2.133515	-.058485
Lt Central ht	1	2	.1180000	.3272433	.931#	-.693373	.929373
	1	3	-1.5390000*	.3272433	.000**	-2.350373	-.727627
	2	3	-1.6570000*	.3272433	.000**	-2.468373	-.845627
Lt Lateral ht	1	2	-.0180000	.3073811	.998#	-.780126	.744126
	1	3	-1.4370000*	.3073811	.000**	-2.199126	-.674874
	2	3	-1.4190000*	.3073811	.000**	-2.181126	-.656874
Lt Canine ht	1	2	.0940000	.5741334	.985#	-1.329517	1.517517
	1	3	-1.0010000	.5741334	.208#	-2.424517	.422517
	2	3	-1.0950000	.5741334	.156#	-2.518517	.328517
Rt central width	1	2	.4580000	.2473318	.172#	-.155239	1.071239

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	1	3	-.3120000	.2473318	.429#	-.925239	.301239
	2	3	-.7700000*	.2473318	.012*	-1.383239	-.156761
Rt Lateral width	1	2	.72000	.32175	.083#	-.0777	1.5177
	1	3	.18400	.32175	.836#	-.6137	.9817
	2	3	-.53600	.32175	.236#	-1.3337	.2617
Rt Canine width	1	2	.3780000	.2362726	.263#	-.207818	.963818
	1	3	.2970000	.2362726	.431#	-.288818	.882818
	2	3	-.0810000	.2362726	.937#	-.666818	.504818
Lt Central width	1	2	.2970000	.2106403	.350#	-.225265	.819265
	1	3	-.1740000	.2106403	.690#	-.696265	.348265
	2	3	-.4710000	.2106403	.083#	-.993265	.051265
Lt Lateral width	1	2	.3330000	.4422965	.734#	-.763638	1.429638
	1	3	-.3030000	.4422965	.774#	-1.399638	.793638
	2	3	-.6360000	.4422965	.336#	-1.732638	.460638
Lt Canine width	1	2	.38100	.24660	.287#	-.2304	.9924
	1	3	.06900	.24660	.958#	-.5424	.6804
	2	3	-.31200	.24660	.427#	-.9234	.2994

Reliability Statistics – Table 2

	Cronbach's Alpha		Intraclass Correlation[a]	95%v Lower Bound	95%v Upper Bound	Value	P value
Rt central ht	.719	Single Measures	.460	.067	.802	3.558	.011*
		Average Measures	.719	.177	.924	3.558	.011*
Rt Lateral ht	.579	Single Measures	.314	-.068	.722	2.373	.057#
		Average Measures	.579	-.234	.886	2.373	.057#
Rt Canine ht	.531	Single Measures	.274	-.100	.697	2.133	.082#
		Average Measures	.531	-.373	.873	2.133	.082#
Lt Central ht	.454	Single Measures	.217	-.142	.659	1.833	.131#
		Average Measures	.454	-.598	.853	1.833	.131#
Lt Lateral ht	.577	Single Measures	.312	-.069	.721	2.362	.058#
		Average Measures	.577	-.240	.886	2.362	.058#
Lt Canine ht	.668	Single Measures	.402	.009	.772	3.013	.022*

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		Average Measures	.668	.028	.910	3.013	.022*
Rt central width	-.038	Single Measures	-.013	-.288	.461	.963	.500#
		Average Measures	-.038	-2.042	.719	.963	.500#
Rt Lateral width	.775	Single Measures	.535	.148	.838	4.453	.003**
		Average Measures	.775	.342	.939	4.453	.003**
Rt Canine width	.340	Single Measures	.147	-.192	.606	1.516	.216#
		Average Measures	.340	-.932	.822	1.516	.216#
Lt Central width	.024	Single Measures	.008	-.277	.482	1.025	.458#
		Average Measures	.024	-1.858	.736	1.025	.458#
Lt Lateral width	.745	Single Measures	.494	.102	.819	3.929	.007**
		Average Measures	.745	.255	.931	3.929	.007**
Lt Canine width	.571	Single Measures	.308	-.073	.718	2.333	.060#
		Average Measures	.571	-.256	.884	2.333	.060#

Discussion

A number of studies have evaluated the accuracy of the linear and dental arch measurements comparing the plaster model with a digital model obtained by scanning the physical plaster model. Sousa et al. (13) and Quimby et al. (17) found no statistically significant differences between manual and digital measurements.

Santoro et al. (4) found statistically significant differences in tooth size and overbite, although it is considered clinically insignificant.

Muller et al. (14) evaluated the Bolton ratio and arch length and found that the digital model needs less time and it is quite reliable.

Unlike previous studies, the present study compares conventional plaster models with digital models obtained by LED scanner and CBCT derieved digital models. Specifically the study evaluated the validity and reliability of LED scanner and CBCT derived models in measuring parameters of smile aesthetics compared with measurements on plaster models.

For most of the linear measurements made on the digital models, no statistically significant differences were found when compared to measurements made manually with a digital calliper on a plaster model of dental arches.

According to Inter technique comparison There was a statistically significant difference seen for the values between the groups ($p<0.05$) for Rt central width with higher values in CBCT and least in LED There was a statistically non significant difference seen for the values between the groups ($p>0.05$) for Lt Canine ht , Rt Lateral width ,Rt Canine width, Lt Central width, Lt Lateral width, Lt Canine width.

However, in contrast to the results of Camardella et al. (8), in the present study most of the distances measured on digital models were slightly smaller compared to the measurements on plaster models. These differences may be due to a number of reasons: (1) there are no physical barriers in the positioning of the points in the digital model; (2) the digital model is not affected or damaged by the positioning of tip of the calliper; (3) smaller measurements in the plaster model may be due to shrinkage or possible dimensional changes of the alginate impressions; (4) with the digital software it is possible to evaluate the contact points on an enlarged image.

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Digital models of the jaws can also be combined with conical beam computed tomographic scans to provide a real view of the anatomy and position of teeth which is useful both in orthodontics (to assess root position) and in oral surgery (to plan surgery and make surgical templates) (21, 22). Moreover, the orthodontic software offers the possibility to observe, prior to orthodontic treatment, how the position correction of the dental elements influences the tooth contacts, the gingival contour and the surrounding tissues. This feature is very useful to evaluate the aesthetic result at the dental and soft tissue level.

Conclusion

Although various techniques are available which are close to gold standard.According to my study There is no match between the three techniques, Hence gold standard is considered as reliable and correct value than other techniques.

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