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Comparing the Accuracy of Dental Measurements – Digital vs Manual: an In-Vivo Study

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Abstract

Aim: The purpose of this in-vivo study is to determine and compare the accuracy of dental measurements calculated on physical and digital models with the measurements taken directly from the patients' mouth.
Methods: This study was performed on 40 subjects. Forty maxillary impressions were produced using a condensation silicone putty material and constructed into a physical model. A digital vernier caliper was utilized to take direct measurements from the patients' mouth as well as from the physical models. CS 3600® was employed for direct intra-oral scanning for the subjects' dentition and generating the digital model. Three-dimensional reverse engineering software was used to make measurements on the digital model. One-way ANOVA test was used to determine the accuracy between the control group, physical models, and virtual group. Tukey's post-hoc analysis was done to compare between the individual group.
Results: There were no statistically significant differences between the physical (p-value=0.254) and virtual models (p-value = 0.168) as compared to those measurements taken directly from the mouth.
Conclusion: The results of the current study demonstrate that intraoral scans are clinically sound to be used in diagnosis and treatment planning in dentistry and provide a professional and well-grounded substitute to the use of conventional plaster models.

Keywords: CS 3600, Digital Models, Intraoral Scanner

1. Background

Since the latter half of the eighteenth century, intraoral impressions have been widely employed in the field of dentistry, and they still remain an area of crucial interest amongst dentists. Evolutionary changes over a couple of centuries have been observed in relation to the techniques of making dental impressions that are inclusive of molded wax, compounds, reversible and irreversible hydrocolloids, and synthetic rubbers. Intraoral impressions are fundamental to a plethora of procedures including therapeutic planning, diagnostics, patient communications, cast fabrications, and preparing restorations (1-4).

In modern dentistry, digital impressions, and 3D models offer promising roles in a variety of dental procedures. This cutting-edge technology has proved to be a great asset - both for the clinicians and the patients. Moreover, the ability of this technology to generate 3D virtual images makes the need for conventional impressions redundant (5-8). The perks of this digital revolution have significantly ameliorated the procedure of orthodontic treatment. The substitution of alginate impressions by digital impressions has led to a paradigm shift in orthodontics (9). These digital models are useful for the analysis of teeth and occlusion, treatment simulation, appliance design and fabrication, and treatment effects (10).

The traditional method has a cumbersome approach that involves the manipulation of impression material followed by loading it onto the tray, administering it into the patient's mouth, and stabilizing the tray until a desirable impression is achieved. The intraoral scanner has eased off this burden and produces a digital impression by directly acquiring the information from the mouth. Furthermore, the features of intraoral scanners like pausing the process and continuing it for multiple times favor patient comfort during the process.

Succinctly, digital models can prove to be very promising in orthodontic treatments and thus, in order to incorporate them in a full-fledged manner, it is imperative to ascertain the level of their accuracy. This study attempts to find answers to these questions on accuracy of digital impressions by comparing certain dental measurements obtained through digital impressions via direct intra-oral scanning versus those measurements obtained through the conventional plaster models.

2.Methods

An in vivo study was carried out on 40 subjects and their informed consent was acquired. This study was approved by Ahmedabad Dental College Ethics Committee. The age distribution ranged from 19 to 26 years, with a mean age of 22.5 years. The gender wise distribution of the sample was 20 males and 20 females.

Inclusion criteria were: (1) a full complement of permanent maxillary teeth from the first molar to contralateral first molar and (2) well-aligned teeth. Exclusion criteria were: (1) teeth with large carious lesions or enamel defects, (2) prosthetic restorative teeth, (3) remaining deciduous teeth, and (4) impacted or supernumerary teeth.

The patients who matched the inclusion criteria were selected and the dental measurements were taken intraorally with the help of a digital vernier caliper (Aerospace A6DIGVC, 150 mm, Digimatic Vernier Caliper, India). The measurements obtained from this method were labelled as the control group (Fig. 1).

Elastomeric impression material consisting of condensation silicone putty impression material (Zetaplus, Zhermack S.P.A., Badia Polesine, Rovigo, Italy) was used to take the intraoral impression, and immediately poured with type IV die stone (Pearl Stone, Asian Paints, Gujarat). The measurements were made on these physical models with the help of a digital vernier caliper (Fig. 2).

For the digital impression, the subjects' dentitions were scanned with an intraoral scanner (CS 3600®, Carestream, Atlanta, USA) (Fig. 3). CS 3600® is the second IOS manufactured by Carestream, which came into the market in 2016. CS 3600® works based on the concept of the active speed 3D video. CS 3600® is well-equipped with interchangeable and autoclavable tips of various sizes and orientations to allow scanning, even in the most difficult areas in the mouth. CS 3600® is a powerfully structured LED light scanner that does not need powder and exhibits the ability to deliver high-quality color images.

Figure 1. Intraoral Measurements: (1A) mesio-distal width of central incisor, (1B) canine height, (1C) intercanine width, (1D) intermolar width, (1E) midline to first premolar, (1F) midline to first molar

Figure 2. Physical model measurements: (2A) mesio-distal width of central incisor, (2B) canine height, (2C) inter-canine width, (2D) inter-molar width, (2E) midline to first premolar, (2F) midline to first molar

All scans with the CS 3600 scanner were recorded by the identical examiner in a set order based to the manufacturer's directions. Scanning was initiated from the first quadrant followed by the second, third, and fourth quadrant respectively. The CS 3600 was held at a 90° angle to the occlusal surface of the teeth. Slowly, the CS 3600 tip was moved along the occlusal surface to scan the remaining teeth. After occlusal surface scanning was completed, scanning of the lingual surface and the buccal surface of teeth was done. Upper and lower arches were similarly scanned. The digital dental models obtained were then imported into 3D reverse engineering software (Rapidform TM 2006, INUS Technology, Seoul, Korea). After importing the file into the software, 3D re-orientation of the study models with correct occlusal planes and inter-arch relationships was done to obtain the required occlusal template of the undigitized arch upon which digitization and measurements was carried out (Fig. 4).

Measurements obtained were: (1) tooth width, mesio-distal (MD) width of the central incisor (CI) (maximum mesiodistal diameter of the tooth); (2) tooth height, canine height (from gingival zenith to the cusp tip); (3) arch width, inter-canine width (distance between cusp tips of opposite canines), inter-molar width (distance between mesio-buccal cusp tips of opposite first molars); (4) arch length, midline to first premolar (from midline to buccal cusp tip of first premolar), midline to first molar (from midline to mesio-buccal cusp tip of first molar).

Each measurement from each group was carried out thrice at an interval of 15 days to remove intra-observer bias. The measurements were then statistically analyzed to determine the accuracy of the measurements obtained from physical models and virtual models of the control group. One-way ANOVA test was used to compare the measurements between the control group, physical models, and virtual models. Further analysis was done using post-hoc test to compare between the individual groups.

Figure 3. Intraoral scanner - CS 3600

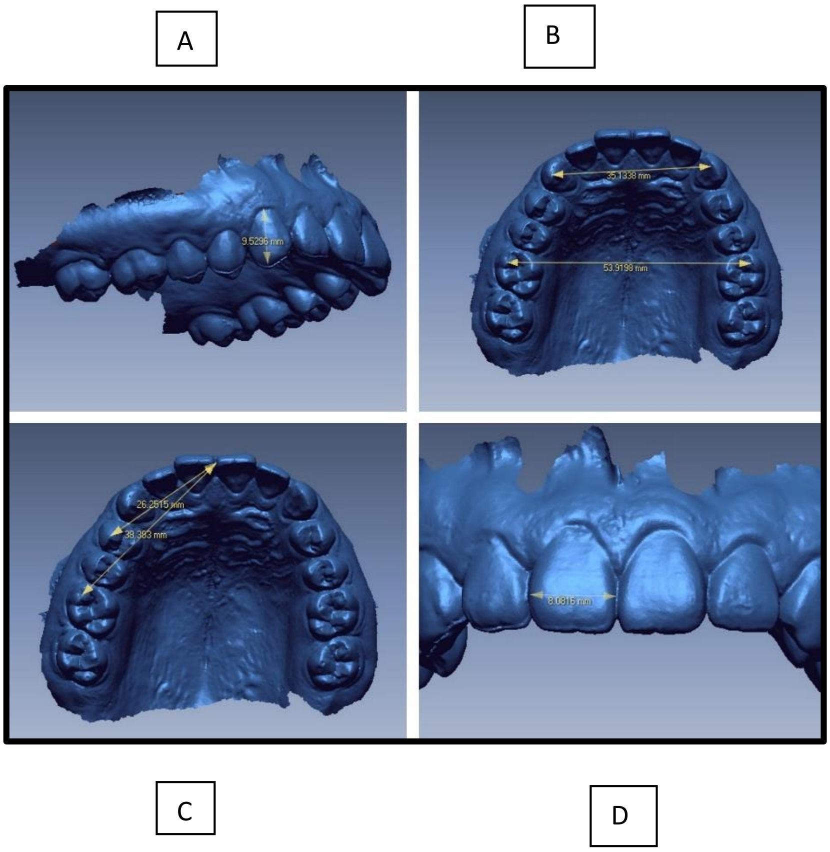

Figure 4. Virtual model measurements: (A) canine height, (B) inter-canine width and inter-molar width, (C) midline to first premolar and midline to first molar, (D) mesio-distal width of central incisor

3.Results

The means and standard deviations for the intra-arch measurements from the control group, physical models, and virtual models are shown in Table 1. Table 2 shows post-hoc analysis comparison between the individual groups. The results show that there is statistically non-significant difference between the control group, physical models, and virtual models as suggested by p-value.

Table 1. Comparison of dental measurements among all groups.

Measurements		Control group	Physical models	Virtual models	P value
MD Width of CI	Mean	8.59	8.57	8.61	0.078
	SD	0.52	0.52	0.51	
Height of Canine	Mean	9.12	9.13	9.15	0.127
	SD	1.16	1.17	1.17	
Inter-canine Width	Mean	34.51	34.52	34.49	0.083
	SD	2.45	2.43	2.46	
Inter-molar Width	Mean	52.25	52.27	52.24	0.064
	SD	2.72	2.73	2.73	
Midline to First Premolar (Anterior Arch Length)	Mean	26.16	26.16	26.17	0.351
	SD	1.51	1.5	1.51	
Midline to First Molar (Arch Length)	Mean	38.35	38.34	38.37	0.431
	SD	2.08	2.08	2.07	

Table 2. Post-hoc analysis showing comparison between individual groups

Groups		MD Width of CI	Canine Height	Inter-canine Width	Inter-molar Width	Midline to First Premolar	Midline to First Molar
		P value	P value	P value	P value	P value	P value
Control Group	Physical Models	0.077	1.000	0.243	0.111	1.000	0.254
	Virtual Models	0.157	0.654	0.058	0.670	0.506	0.168
Physical Models	Virtual Models	0.063	0.098	0.053	0.163	1.000	0.064

4. Discussion

In orthodontics, plaster and stone casts play a crucial role in providing diagnostic information that helps the clinician to make sound treatment plans, to assess treatment results, and to fabricate orthodontic appliances and retainers required for and after the treatment (11). For this, accurate replication of both hard and soft tissue relationships is an essential requirement. In traditional orthodontic practice, a single cast is fabricated with the use of alginate impressions, and this very cast is utilized for several reasons like diagnosis, treatment planning, diagnostic wax-ups, and designing of appliances. This conventional method seems to be quite reliable; however, some drawbacks associated with it cannot be neglected. They are technique sensitive, labor-intensive process, cause patient discomfort (particularly those with a strong gag reflex), risk of damage or loss of plaster models, and need for their storage.

Digital models are becoming increasingly popular amongst clinicians as a reliable alternative to the classical plaster and stone models due to their most important benefits as they are easy to access and store. Literature has revealed that computer-based models are valid as well as reliable, which means that digital media could be safely employed in clinical orthodontics. The orthodontists' choice of impression material and its manipulation should be such that the resultant cast possesses desirable accuracy for its subsequent clinical use.

An in vivo study was done to verify the accuracy of the dental measurements made directly in the subject's mouth, on stone cast, and on virtual models. A digital vernier caliper was utilized to take direct measurements from a patient's mouth. Forty maxillary impressions were made manually using silicone putty material and were poured immediately with pearl orthodontic stone (Dental stone type IV). Then the measurements were checked using a digital vernier caliper. CS 3600® was employed for direct intra-oral scanning for the subject's dentition and for generating the digital model. Rapidform 3D reverse engineering software was used to make measurements on the digital model. All the measurements in each group were taken thrice on days 1, 15, and 30 to eliminate intra-observer bias. Interestingly, the results demonstrated that there was statistically non-significant difference between the control group, physical, and virtual models.

Zilberman et al (12) evaluated the validity of tooth size and arch width measurements using conventional models versus OrthoCad virtual models. Their results have shown that both methods are valid and reproducible for both tooth size and arch width. Joshua C. Treesh et al (13) carried out a study to determine the accuracy of complete arch measurement of the intraoral scanners. Four intraoral scanners were evaluated (CEREC Bluecam, CEREC Omnicam, TRIOS Color, and Carestream CS 3500). All of the scanners were prone to underestimate the size of the reference file, with exception of the Carestream CS 3500, which was more variable. Seo-Hyun Park et al (14) evaluated the reliability, reproducibility, and validity of digital orthodontic measurements based on various digital models among young patients. They used the CS 3600 as an intraoral scanner. The measurements based on the digital program manifested high reliability, reproducibility, and accuracy compared to the conventional measurement.

The main focus of the current research was to determine if digital models offer a valid and clinically practical option to plaster models. Such developments could offer a plethora of benefits such as reduced storage requirements, quick access to digital information, convenient transfer of data, versatility, and financial savings. This study not only substantiates these proven benefits but also concludes no significant compromise to accuracy of occlusal information. Validity of digital models have been confirmed as an option to plaster models and digital models could soon become a favorite for occlusal records.

Conclusion

This in vivo study was done to determine the accuracy of dental measurements derived from physical and digital models with the measurements carried out in the subject's mouth manually with the help of a vernier caliper.

The study concluded that:

The measurements obtained from the physical models derived from elastomeric impressions are as accurate as the measurements taken directly from the patient's mouth.

The measurements obtained from the virtual models derived from an intraoral scanner are as accurate as the measurements taken directly from the patient's mouth.

The study proves that digital models could promise a valid option to the traditional plaster models with the accuracy and reliability comparable to that of the latter.

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