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Original Research

Comparison of Measurements on Conventional Plaster Model and Computer-Aided Digital Dental Models

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ABSTRACT

Objective: The objective of the present study was to examine the veracity and precision of measurements obtained from plaster models and digital models of subjects presenting with different malocclusion patterns.

Methods: A total of 68 orthodontic patients, who had requested treatment were randomly selected and included in the study and classified as Class I (n=20), Class II (n=20) and Class III (n=18). The first group underwent an alginate impression procedure, which involved taking measurements from both the upper and lower jaws. Subsequently, plaster models were created through the casting of these impressions. In the second group, digital models were created by digitizing the patients' upper and lower jaws with an intraoral scanner. In the third group, the plaster models were digitized via a camera, thus creating a digital model record. A series of measurements was taken on both the digital and plaster models. These included intercanine width, intermolar width, overjet, overbite, mesiodistal dimensions of the teeth, as well as the Bolton, Hayes-Nance and midline shift analyses. The reliability of the measurements taken on the plaster models with electronic calipers and on the digital models with 3Shape Ortho Analyzer software was then evaluated.

Results: The results of the analyses revealed no statistically significant differences between the groups ($p>0.05$). Statistically significant differences were observed between Class II and Class III malocclusions in Group 1 in terms of mandibular intermolar distance measurements, and between Class I malocclusion, Class II and Class III malocclusions in Group 3 in terms of Bolton 12 teeth measurements ($p < 0.05$).

Conclusion: The measurements derived from plaster models, digital models obtained directly with an intraoral camera and digital models generated through the scanning of the plaster models, and demonstrated comparable reliability. In orthodontics, digital models represent an acceptable alternative to plaster models for the purpose of taking measurements.

Keywords: intraoral scanner, digital model, plaster model, model analysis

INTRODUCTION

For orthodontic treatment to succeed, it must be based on a comprehensive diagnosis and a detailed treatment plan. Orthodontic documentation is essential for accurate diagnosis and effective treatment planning. Orthodontic models play a critical role in these records and are fundamental to the diagnosis process [1,2]. Model analyses are essential for accurate diagnosis and treatment planning [3,4]. Until recently, plaster models were the primary diagnostic tool in this context. The use of plaster models in the context of orthodontic treatment has a long history, with these models being recognized as an essential component of the records taken before and after treatment. In addition to their use as records, plaster models are employed in a number of other ways, including in diagnosis, treatment planning, communication between different disciplines, case presentations, and the assessment of treatment progress and results. One of the methods presented in literature for comparison purposes is the analysis of plaster models obtained from patients both before and after treatment [3].

The storage, preservation and repeated measurement of plaster models in long-term studies represents a significant challenge [2,5,6]. The use of digital models has been demonstrated to address several issues associated with traditional plaster models, including their susceptibility to breakage, the potential for error due to repeated measurement and the need for extensive archiving space in busy orthodontic clinics. The integration of digital models may therefore represent a crucial step in the transition to digital records. For this reason, efforts have been made to establish the necessary infrastructure for software and analysis [7,8]. As a consequence of these attempts, there has been a focus on obtaining models within a digital environment and performing analyses based on these models.

Main Points

- Three distinct orthodontic modelling techniques were employed.
- The specimens were classified according to the three categories of malocclusion, classified as Class 1, 2 and 3.
- The reliability of digital models is comparable to that of plaster models.

Digital models, created using a variety of computer software, are now being employed with greater frequency as a means of providing detailed information regarding a patient's diagnosis and treatment plan, the effects of treatment, and any potential tooth movement [9].

The concept of a three-dimensional digital orthodontic model shows considerable promise. The electronic storage of patients' information and plaster models would provide a solution to the issues of model storage, breakage, reproduction and maintenance, while also improving clinical procedures and facilitating communication between different specialties [2,3,8].

In literature, studies have been conducted to compare the reliability of measurements obtained from plaster models with those obtained from digital models. In these studies, there are several limitations, including insufficient model analysis [3,8], a small sample size [5,9], and an absence of malocclusion classification [3,5] regarding the individuals included in the study. Furthermore, previous studies employed the creation of virtual models through scanning plaster models using the OrthoCad system [8], and did not utilize direct intraoral camera 3D (three-dimensional) scans. The TRIOS system (3Shape, Copenhagen, Denmark) provides the capability to perform both intraoral 3D scanning and scanning from plaster models, thereby obtaining digital models. Further studies are required to fully assess the potential of this new system.

The objective of this study was to assess the reliability of plaster models produced using conventional alginate materials and computer-aided digital models through the comparison of different measurement techniques. The null hypothesis was that there would be no difference between three measurement methods.

MATERIAL AND METHODS

The study included patients with Class I (20), Class II (20) and Class III (18) malocclusion who had applied to the Department of Orthodontics, Faculty of Dentistry, Gaziantep University. In this clinical study, ethical approval was obtained from the Gaziantep University Clinical Research Ethics Committee on 20/06/2018 with approval number 135, in accordance with the Declaration of Helsinki. Based on the power analysis, 17 subjects per group were considered sufficient, assuming an alpha error of 0.05, 80% power, and an effect size of 0.45. The number of patients included in the groups was determined in accordance with the aforementioned analysis. The participants in the study were adolescents, aged between 14 and 18 years.

The patients included in the study were required to meet the following criteria: complete permanent tooth alignment, the absence of two- or three-surface filling or prosthetic applications, the absence of anomalies, atresia or caries in their teeth, the absence of previous orthodontic treatment and the presentation of a complaint of orthodontic malocclusion at the clinic. The exclusion criteria were defined as the presence of any missing teeth and a history of previous orthodontic treatment.

The data obtained from the 58 patients with diverse malocclusions included in the study were classified into three groups based on the disparity in the analytical techniques employed for the models. In the initial group, impressions were taken using alginate from the upper and lower jaws of the patients, and plaster models were obtained through casting the impressions. Firstly, plastic trays of an appropriate size were selected, and impressions were obtained from the upper and lower jaws using an alginate impression product (CA 37 Cavex, Haarlem, The Netherlands). Blue hard plaster (Zhermack Elite Dental Stones, Bovazecchino, Badia Polesine (Rovigo), Italy) was poured without delaying the process to minimize dimensional changes, and plaster models were produced (Figure 1). In order to ascertain the relationship between the upper and lower jaws in the models, bite was recorded with pink wax. The second group comprised the creation of digital models through the scanning of the upper and lower jaws of patients with the use of an intraoral scanner (TRIOS; 3Shape, Copenhagen, Denmark) (Figure 2). In the third group, a digital model record was generated by scanning the plaster models with intraoral scanner (TRIOS; 3Shape, Copenhagen, Denmark) (Figure 3). The reliability of these methods was subsequently assessed.

Model analyses were conducted employing a digital electronic caliper (OEM KMP 0-150 mm, accuracy: 0.01 mm) on the plaster models obtained for Group 1 (Figure 4). The measurements obtained from Groups 2 and 3 were determined on digital models using Ortho Analyzer (3Shape) software (Figure 5 A-B).

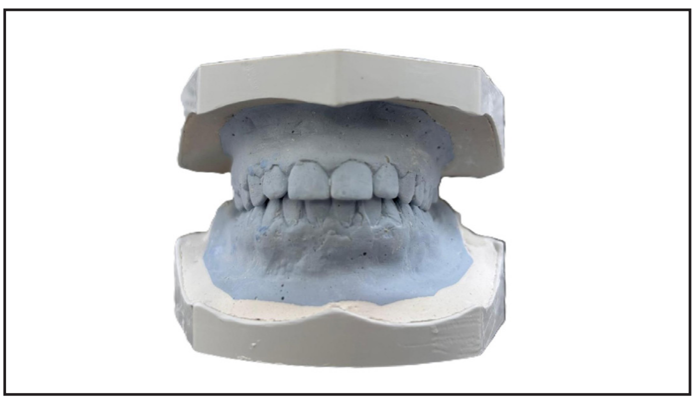

Figure 1. Obtained plaster models

Figure 3. Digital models obtained from plaster model scanning

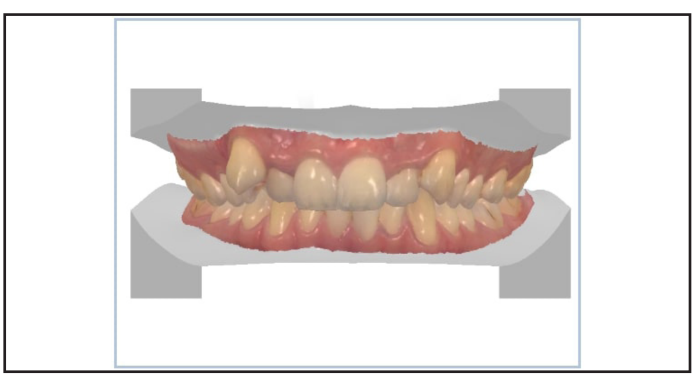

Figure 2. Digital models obtained from intraoral scanning

Figure 4. Measurements on the plaster model with callipers

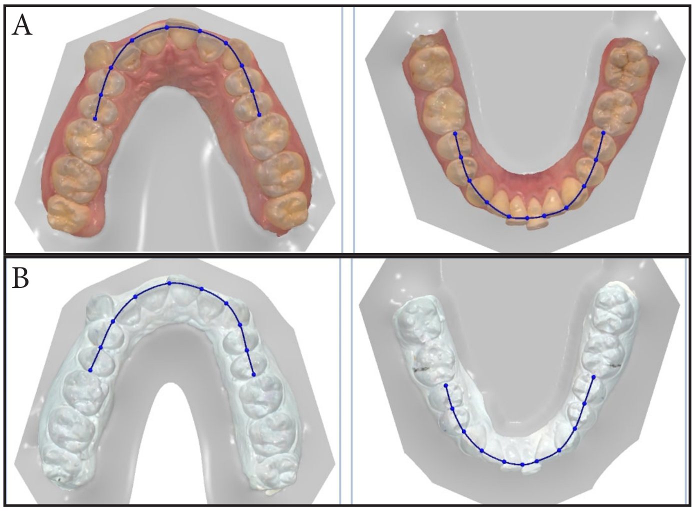

Figure 5. A-B Measurements on the digital models with ortho analyser software

Measurements used in model analyses are; intercanine width (distance between the right and left canine cusps), intermolar width (distance between the mesio-buccal cusps of the right and left first molars), overjet (distance of the incisor edge of the upper central incisor to the vestibular surface of the lower central incisor measured parallel to the plane of occlusion), overbite (distance of the incisor edge points of the upper and lower central incisors perpendicular to the plane of occlusion), the mesiodistal dimensions of the teeth (the widest distance between the mesial and distal surfaces of the teeth), Bolton's Analysis (the size harmony between the mandibular and maxillary teeth is evaluated), Hayes Nance Analysis (the required arch length is subtracted from the existing arch length to determine the space shortage or excess) and the amount of midline shift (the distance between the upper and lower midline lines according to the frontal plane).

Statistical Analysis

The normal distribution of the values was evaluated using the Shapiro-Wilk test. The Kruskal-Wallis analysis was applied to evaluate independent groups that did not conform to a normal distribution. The All Pairwise multiple comparison test, a type of post-hoc analysis, was employed to ascertain which group was responsible for the significant results obtained in the Kruskal-Wallis test. In order to analyse categorical variables, the researchers employed a Chi-square test. Descriptive statistics were presented as mean ± standard deviation (SD) values. A statistical analysis was performed using the SPSS Windows version 24.0 software package (Statistical Package for Social Sciences, Ver:24.0, Illions, USA). A p-value of less than 0.05 was determined to be statistically significant.

RESULTS

A total of 20 individuals (11 girls and 9 boys) with Class I malocclusion, 20 individuals (13 girls and 7 boys) with Class II malocclusion and 17 individuals (5 girls and 12 boys) with Class III malocclusion were included in the study.

The mean chronological age of the patients included in the study was 16.03 ± 0.23 years for those with Class I malocclusion, 16.20 ± 0.20 years for those with Class II malocclusion and 16.16 ± 0.26 years for those with Class III malocclusion. Patients with different malocclusions included in the study were comparable in terms of age and gender ($p > 0.05$).

Table 1 presents the statistical data pertaining to the measurements of direct plaster models, measurements obtained through the utilization of three-dimensional intraoral scanning, measurements obtained through three-dimensional scanning of the plaster model, and the p-values associated with the comparative analysis of the measurements.

A statistically significant difference was observed between Class II and Class III malocclusion in Group 1 in mandibular intermolar distance measurements ($p < 0.021$). Furthermore, a statistically significant difference was identified between Class I, Class II ($p < 0.005$) and Class III malocclusion ($p < 0.009$) in Group 3 in Bolton 12 teeth measurements (Table 1).

Table 1. Comparison of 3 different measurement methods applied on individuals with different malocclusions

		Malocclusion						
Measurements		**Class 1 Mean (SD)**	**Class 2 Mean (SD)**	**Class 3 Mean (SD)**	**1-2-3**	**1-2**	**2-3**	**1-3**
Overjet	Group 1	2.78 (0.44)	3.70 (0.38)	-0.67(0.69)	**0.00***			
	Group 2	2.73 (0.50)	3.54 (0.38)	-0.75 (0.69)	**0.00***			
	Group 3	2.67 (0.51)	3.49 (0.38)	-0.73(0.66)	**0.00***			

	P	0.987	0.924	0.997				
Overbite	Group 1	1.84 (0.47)	3.21(0.57)	0.40(0.62)	**0.015***			
	Group 2	1.64 (0.45)	2.83 (0.60)	0.42 (0.69)	**0.008***			
	Group 3	3.41 (1.78)	2.72(0.58)	0.19(0.66)	**0.01***			
	P	0.463	0.838	0.964				
Intercanin Distance (Maxilla)	Group 1	33.47 (0.88)	33.89 (0.70)	35.19(0.82)	0.36			
	Group 2	33.66 (0.89)	34.28 (0.63)	35.33(0.81)	0.267			
	Group 3	33.48 (0.91)	34.11(0.59)	35.36(0.77)	0.407			
	P	0.987	0.915	0.987				
Intercanin Distance (Mandible)	Group 1	26.37 (0.48)	26.02(0.46)	28.15(0.68)	0.107			
	Group 2	26.62 (0.44)	26.57(0.44)	28.20(0.69)	0.081			
	Group 3	26.36 (0.46)	26.46 (0.43)	28.21 (0.67)	0.06			
	P	0.905	0.672	0.998				
Intermolar Distance (Maxilla)	Group 1	50.00 (0.76)	48.51 (1.15)	51.78(1.06)	0.265			
	Group 2	50.74 (0.77)	49.69 (1.09)	52.16 (1.08)	0.171			
	Group 3	50.33 (0.77)	40.05(1.06)	51.86(1.06)	0.189			
	P	0.796	0.755	0.967				
Intermolar Distance (Mandible)	Group 1	44.29 (0.55)	42.94 (0.69)	45.93(0.87)	**0.048***		**❖.021**	
	Group 2	44.86 (0.57)	43.43 (0.73)	46.13(0.92)	0.103			
	Group 3	44.13 (0.55)	43.38 (0.70)	45.89(0.85)	**0.05***			
	P	0.626	0.877	0.979				
Midline Shift	Group 1	1.26 (0.16)	1.38(0.26)	1.28(0.21)	0.995			
	Group 2	1.22 (0.16)	1.42 (0.25)	1.27(0.20)	0.986			
	Group 3	1.27 (0.16)	1.47 (0.25)	1.29 (0.21)	0.981			
	P	0.975	0.973	0.997				
Hayes Nance (Maxilla)	Group 1	-2.53 (1.06)	-3.04 (1.04)	-2.20(1.02)	0.711			
	Group 2	-2.88 (1.16)	-3.61 (1.03)	-2.44 (0.93)	0.908			
	Group 3	-2.26 (1.06)	-2.92 (0.87)	-2.17(0.98)	0.882			
	P	0.925	0.868	0.977				
Hayes Nance (Mandible)	Group 1	-1.92 (0.84)	-2.09 (0.77)	-1.07(0.99)	0.665			
	Group 2	-1.66 (0.75)	-2.23 (0.68)	-1.09 (0.88)	0.787			
	Group 3	-1.51 (0.87)	-1.49 (0.71)	-0.72(0.92)	0.717			
	P	0.941	0.739	0.952				
BOLTON 6	Group 1	1.83 (0.21)	1.83 (0.21)	1.10(0.18)	0.253			
	Group 2	1.80 (0.27)	1.80 (0.27)	1.15 (0.21)	0.168			
	Group 3	1.65 (0.23)	1.65 (0.23)	1.31(0.20)	0.065			
	P	0.861	0.273	0.744				
BOLTON 12	Group 1	2.39(0.21)	1.44(0.34)	1.41(0.26)	0.475			
	Group 2	2.43 (0.46)	1.72 (0.28)	1.87(0.36)	0.105			
	Group 3	2.46 (0.40)	1.10(0.19)	1.65(0.23)	**0.007***	**❖.005**		**❖.009**
	P	0.991	0.709	0.552				

Significant at 0.05<p level * Kruskal Wallis ❖ All Pairwise multiple comparison test

Group 1: Model analyses were conducted employing a digital electronic caliper on the plaster models

Group 2: Model analyses were conducted employing a software Ortho Analyzer (3Shape) on the virtual models (obtained from intraoral scanning)

Group 3: Model analyses were conducted employing a software Ortho Analyzer (3Shape) on the virtual models (obtained from plaster model scanning)

DISCUSSION

It is of great importance that the precision and consistency of the model analyses employed in the diagnosis and treatment planning of orthodontic patients are of the highest standard. For many years, model analyses have been conducted on plaster models using a variety of calipers to obtain measurements.

The potential for deformation of dental plaster models and the necessity for extensive storage space have prompted the development of digital models. In order for digital models to be considered a replacement for plaster models, it is essential that they provide reliable and accurate results in measurements. In order to ascertain the accuracy of digital models and the measurements made on these models, it is necessary to conduct comparative studies in this field.

This study examined the reliability and accuracy of 3D scanning devices by comparing the models obtained through 3D scanning with measurements taken on a plaster model, which is considered the gold standard. The model analyses were conducted by a single researcher, employing three distinct methodologies. It was hypothesized that there would be no difference between the measurement methods. This hypothesis was corroborated by the finding that the methods used for the measurements yielded no significant difference. The importance of this study is highlighted by the substantial sample size and a large number of measurements that were compared.

In numerous preceding studies, the efficacy of 3D systems and conventional plaster model measurement techniques was evaluated, giving rise to disparate outcomes. Zilberman et al. conducted a comparison between measurements taken on plaster models and digital models generated using the OrthoCAD system. Although no statistically significant difference was identified in the obtained results, the researchers concluded that measurements taken using electronic calipers on the plaster model demonstrated enhanced accuracy and reliability [10]. It was stated that 3D systems are suitable for clinical use, but insufficient for research purposes. Although these results indirectly support this study, the idea that digital models are only suitable for clinical use is not corroborated.

Souso et al. conducted a study on 20 dental models using a 3Shape intraoral three-dimensional scanning device and Geomagic Studio 5 model analysis software. The results demonstrated that there was no statistically significant discrepancy between the arc width and length measurements obtained from the virtual and plaster models. The findings of the present study are in accordance with those previously reported by Souso et al. [11]. As reported by Bell et al., no statistically significant difference was found between the two measurement methods when comparing direct measurements made on dental models and data obtained from computer-generated 3D models using the photostereography technique [12]. This result is consistent with other studies in the literature [6,13,14]. Nevertheless, other research indicates that measurements made with digital models differ from those obtained with plaster models. Meredith et al. reported that all values except overjet and overbite were measured larger on digital models [15]. The discrepancy was attributed to two factors: firstly, errors occurring during the conversion of plaster models into digital models; secondly, the inability of the 3D scanning system used to transfer the images completely and accurately. In the present study, one of the above-mentioned factors may be the reason for the statistically significant difference in Bolton 12 tooth measurement in Group 3, where digital models were created by scanning plaster models. The discrepancy observed in the Bolton analysis can be attributed to the findings of Baciu et al [16].

In the present study Baciu et al. sought to compare the traditional caliper measurement method with the digital measurement method of DentalCad 3.0 Galway software. This comparison was made on plaster and resin models. The digital measurement method was found to result in the determination of wider mesio-distal distances of the teeth. This finding led to the conclusion that there was a discrepancy between the measurement methods in Bolton analysis. The researchers hypothesised that this discrepancy may be attributable to the scanner's inability to accurately detect contact points during intraoral scanning.

In a study conducted by Uysal et al. comparing dental and alveolar arch width measurements on plaster models between 150 individuals with Class I occlusion and 100 individuals with Class III malocclusion, it was found that mandibular intercanine and intermolar widths were significantly larger in the Class III malocclusion group [17]. The results of this study revealed a comparable outcome, whereby the mandibular intermolar width was identified as being statistically significantly larger in Class III patients of Group 1.

Leifert et al. conducted a comparative analysis of Hayes Nance analyses in digital and plaster models, reporting a statistically significant difference in maxillary arch analysis [8]. They attributed this finding to the inability to accurately measure arch length due to differences in maxillary inclination and the difficulty in marking identical points in each measurement. In the present study, all measurements were conducted by a single investigator, thereby eliminating the potential for inter-individual measurement discrepancies.

Dalstra et al. employed the OrthoCAD system to conduct a study in which they observed that the arc length and overjet values were greater in plaster model measurements [5]. They ascribe this discrepancy to the fact that the measurements obtained using calipers were based on the most protruding surface of the teeth, whereas the software they utilized accounted for the incisal edge. Despite the limitations of intraoral scanning devices, including hygiene concerns [18]and their status as a novel technology for clinicians [19], an analysis of current studies reveals that this field is primed for further advancement. Planning comprehensive studies with a larger sample group, different 3D intraoral scanning devices and different software analysis for dental measurements will provide a more enlightening scientific contribution to this field.

CONCLUSIONS

The measurements obtained from the plaster model, the virtual model and the virtual model created from the plaster model itself exhibited comparable levels of accuracy.

Conflict of Interest: The authors declare that they have no conflicts of interest.

Informed Consent: An informed consent was obtained from all patients and their parents prior to treatment.

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Ethical Approval: Ethical approval was obtained from the Gaziantep University Clinical Research Ethics Committee and ethics committee on 20/06/2018 with approval number 135, in accordance with the Declaration of Helsinki.

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