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CLINICAL RESEARCH:

A Comparative Evaluation of Digital and Conventional Approaches in Orthodontic Space and Tooth Size Analysis: A Retrospective Comparative Study

Una evaluación comparativa de los enfoques digitales y convencionales en el análisis del espacio ortodóntico y el tamaño dental: un estudio comparativo retrospectivo

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ABSTRACT: Aim of the study was to comparatively assess the sensitivity of digital measurements for space discrepancies and tooth size analysis in comparison to conventional plaster models, digital models, and rescanned plaster models. Orthodontic pre-treatment records were obtained from 40 randomly selected patients undergoing orthodontic treatment in the permanent dentition (mean age: 20.83; 14 males, 26 females). Intraoral 3D records and conventional plaster models were collected. Digital measurements were performed using an intraoral scanner (iTero Element, Align Technologies, San Jose, Calif), while conventional measurements were derived from alginate impressions used to create plaster models. These plaster models were subsequently digitized using the same intraoral 3D scanner. All measurements from the digitized models were analyzed using the OrthoCAD software (Cadent, Carlstadt, NJ, USA). No significant differences were observed among the groups for measurements of Hayes-Nance Maxilla Actual, Hayes-Nance Maxilla Required, Hayes-Nance Maxilla Discrepancy, Bolton Overall Maxilla, Bolton Overall Mandible, Bolton Overall Discrepancy, Bolton Overall Ratio (%), Overbite, and Overjet ($p>0.05$). Throughout the study, no variations were observed in Hayes-Nance, Bolton analyses, or overjet-overbite measurements across digital models, plaster models, and digitized plaster models. The mean differences between methods were generally within 1 mm, suggesting clinical comparability for most analyses. However, moderate intra-examiner reliability was observed for Bolton Anterior Ratio and Overbite, indicating that these variables should be interpreted with caution. Within the limitations of this study, scanning plaster models with an intraoral scanner appears to be a feasible and clinically acceptable alternative to direct digital scanning.

KEYWORDS: Models, dental; Orthodontics; Imaging, three-dimensional; Dental impression technique; Reproducibility of results; Observer variation.

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RESUMEN: El objetivo del estudio fue evaluar comparativamente la sensibilidad de las mediciones digitales para discrepancias de espacio y análisis del tamaño dental en comparación con modelos de yeso convencionales, modelos digitales y modelos de yeso reescaneados. Se obtuvieron registros de pretratamiento ortodóncico de 40 pacientes seleccionados aleatoriamente en dentición permanente (edad media: 20,83; 14 hombres, 26 mujeres). Se recopilaron registros intraorales 3D y modelos de yeso convencionales. Las mediciones digitales se realizaron mediante un escáner intraoral (iTero Element, Align Technologies, San José, California), mientras que las mediciones convencionales se obtuvieron de impresiones de alginato utilizadas para crear modelos de yeso. Estos modelos de yeso fueron posteriormente digitalizados con el mismo escáner intraoral 3D. Todas las mediciones de los modelos digitalizados se analizaron con el software OrthoCAD (Cadent, Carlstadt, NJ, EE.UU.). No se observaron diferencias significativas entre los grupos para las mediciones de Hayes-Nance Maxilar Real, Hayes-Nance Maxilar Requerido, Discrepancia Hayes-Nance Maxilar, Bolton Total Maxilar, Bolton Total Mandibular, Discrepancia Bolton Total, Relación Bolton Total (%), Sobremordida y Resalte ($p>0,05$). A lo largo del estudio, no se observaron variaciones en los análisis de Hayes-Nance, Bolton ni en las mediciones de resalte-sobremordida entre modelos digitales, modelos de yeso y modelos de yeso digitalizados. En consecuencia, los modelos convencionales, digitales y los modelos de yeso escaneados intraoralmente pueden utilizarse de forma intercambiable para el análisis.

PALABRAS CLAVE: Modelos dentales; Ortodoncia; Imagen tridimensional; Técnica de impresión dental; Reproducibilidad de resultados; Variación del observador.

INTRODUCTION

Orthodontic models are essential tools in clinical orthodontics, providing a three-dimensional visualization of the patient's oral cavity. They are particularly valuable for assessing the degree and severity of malocclusion, which may not be fully evident during a routine clinical examination (1). One review highlights that orthodontic models are routinely obtained from patients as part of the diagnostic process. Accurate transfer of the patient's dental anatomy and the production of high-quality plaster models are crucial prerequisites for effective dental model analysis. These models serve as foundational tools for assessing malocclusion and guiding treatment planning, ensuring precise alignment and comprehensive evaluation (2). The literature indicates that the recent emergence of digital dental models and software automation has substantially alleviated the challenges associated with traditional model analysis. These advancements have streamlined the process, enhancing accuracy, reducing manual labor, and improving overall efficiency in diagnostic and treatment planning procedures (2). Furthermore, studies have demonstrated that both intraoral scanners and various model types yield accurate and reproducible linear measurements, supporting their reliable use in clinical orthodontic workflows (3,4).

Orthodontic models are essential tools in orthodontic diagnosis and treatment planning. They are utilized for various purposes, including arch length calculations, determining overjet and overbite, and conducting Bolton analysis. Traditionally, orthodontic models have been obtained from plaster and have been considered the gold standard for years (5). However, orthodontic plaster models require significant physical storage space, and due to the brittle nature of plaster, they are prone to breakage and deformation during handling and transportation (6). Additionally, obtaining plaster models requires taking impressions with alginate,

a procedure that can be uncomfortable or challenging for some patients (7).

In today's digital era, orthodontic science has significantly embraced technological advancements. Traditional records are increasingly being replaced by digital alternatives, with digital models now routinely used in many orthodontic clinics (8). These digital records provide sufficient data for diagnosis and treatment planning. They offer practical advantages such as low cost, no need for physical storage space, and the ability to be stored without degradation (9). When the accuracy of measurements such as tooth size, arch width, space discrepancies, overjet, overbite, midline discrepancy, Bolton discrepancy, and molar and canine relationships obtained from digital models is evaluated, it has been found that the results are clinically valid (10).

Findings regarding the accuracy of plaster versus digital models remain inconsistent across the literature (7,10-13), which underscores the need for further investigation. Clinically, access to a model scanner may not always be available; however, orthodontists typically have access to plaster models. This raises the question of whether it is feasible to digitize data obtained from plaster models for treatment purposes. Based on this premise, our hypothesis emerged. The null hypothesis of this study posits that there are no significant differences in model analyses between plaster models, digital models, and intraoral scanner-derived digital models. So this study aims to evaluate the accuracy and sensitivity of digital measurements for space discrepancies and tooth size analysis, comparing them with traditional plaster models. Additionally, it investigates whether rescanning plaster models with an intraoral scanner maintains their analytical precision.

MATERIAL AND METHODS

This study was designed as a retrospective comparative study. The research protocol was approved by the Ethics Committee of Clinical Research of the ****** University (Protocol Number: 2024/01). The required sample size for this study was determined using the G*Power 3.1.9.7 software (Franz Faul, Germany), based on the 'Suryajaya W, Purbiati M, Ismah N. Accuracy of digital dental models and three-dimensional printed dental models in linear measurements and Bolton analysis. J Orthod. 2020;47(2):113-118'. Parameters included α=0.05 (significance level), β=80% (statistical power), and an effect size of 0.5, which indicated a minimum sample size of 40. Accordingly, the study utilized dental casts and digital records, with a planned sample size of 40 casts (n=40) per group. Inclusion criteria were: patients in permanent dentition with complete orthodontic pre-treatment records (both intraoral scans and plaster models), no missing or severely malformed teeth, and no previous orthodontic treatment. Exclusion criteria included craniofacial anomalies or syndromes, and poor-quality impressions or scans. The sample included patients with varying degrees of malocclusion and a range of crowding and spacing severity. Patients were randomly selected using a computer-generated random number sequence applied to the clinic's pre-treatment records archive.

Orthodontic pre-treatment records were collected from 40 randomly selected patients undergoing orthodontic treatment in permanent dentition (mean age: 20.83 years; 14 males, 26 females). Intraoral 3D records and plaster models were obtained for the study. Digital measurements were recorded using an intraoral scanner (iTero Element, Align Technologies, San Jose, Calif), while conven-

tional measurements were taken with alginate impressions, which were later used to create plaster models. These plaster models were subsequently scanned using the same intraoral scanner.

Measurements for the groups obtained with the intraoral 3D scanner were analyzed using the OrthoCAD program (Cadent, Carlstadt, NJ, USA). The mesio-distal tooth dimensions from the plaster models were measured conventionally using a digital caliper, while apical base widths were calculated using brass wire. After measuring the mesio-distal tooth dimensions and apical bases across all three groups, Hayes-Nance and Bolton analyses were performed to evaluate the space discrepancies and tooth size relationships. The measurement procedures are illustrated in Figure 1.

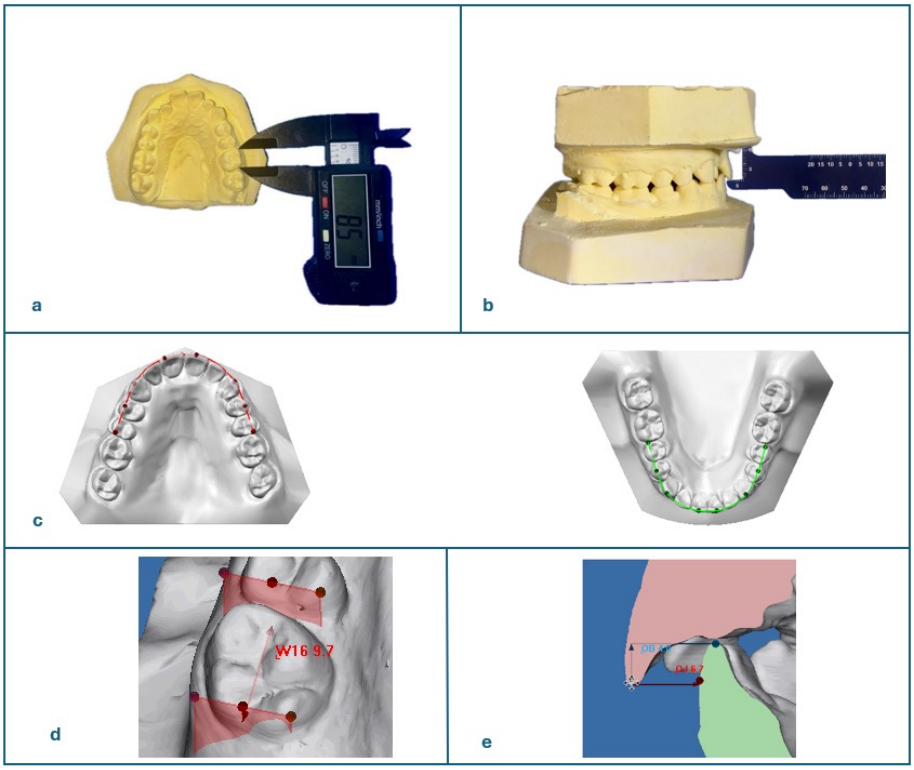


Figure 1. Measurement of; mesiodistal dimension of maxillary 1st molar (a). Measurement of overjet (b). Proper placement of the soft wires according to the Nance method (c). Measurement of mesiodistal dimension of maxillary 1st molar via OrthoCAD (d). Measurement of overjet and overbite via OrthoCAD (e).

STATISTICAL ANALYSIS

The data were analyzed using SPSS v22. Since the same 40 patients contributed measurements across all three model types (plaster, digital, and rescanned), a repeated-measures design was employed. Data normality was assessed using the Shapiro-Wilk test, and homogeneity of variances was evaluated using Levene's test. Where the assumptions of normality and homogeneity of variances were met, a one-way repeated-measures ANOVA was applied to compare the three groups. Where assumptions were violated, the Friedman test was used as a non-parametric alternative. Descriptive statistics were applied to assess the data. Measurement reliability was assessed by repeating all measurements after a 15-day interval. Intra-examiner reliability was evaluated using the

Intraclass Correlation Coefficient (ICC; two-way mixed model, absolute agreement, single measures). Statistical significance was set at $p<0.05$.

RESULTS

No significant differences were observed between the groups in terms of the following parameters: 'Hayes-Nance Maxilla Actual', 'Hayes-Nance Maxilla Required', and 'Hayes-Nance Maxilla Discrepancy' ($p>0.05$) (Table 1), 'Hayes-Nance Mandible Actual', 'Hayes-Nance Mandible Required', and 'Hayes-Nance Mandible Discrepancy' ($p>0.05$) (Table 1), 'Bolton Overall Maxilla', 'Bolton Overall Mandible', 'Bolton Overall Discrepancy', and 'Bolton Overall Ratio (%)' ($p>0.05$) (Table 2), 'Bolton Anterior Maxilla', 'Bolton Anterior Mandible', 'Bolton Anterior Discrepancy', and 'Bolton Anterior Ratio (%)' ($p>0.05$) (Table 2), as well as 'Overbite' and 'Overjet' ($p>0.05$) (Table 3). The high degree of agreement among the three methods, reflected by the non-significant p-values and the narrow confidence intervals reported in Tables 1-3, indicates that these methods are comparable in clinical practice. Intra-examiner reliability based on repeated measurements at a 15-day interval is presented in Table 4 (ICC and 95% Confidence Intervals). While most variables demonstrated high to excellent reliability (ICC>0.90), moderate reliability was observed for Bolton Anterior Ratio (%) (ICC=0.490), Bolton Anterior Discrepancy (ICC=0.812), and Overbite (ICC=0.756). These variables should be interpreted with caution, as they may be more susceptible to measurement variability.

Table 1. Comparison of maxillary and mandibular Hayes-Nance measurements across different model types.

	Group	n	Mean	Median (min;max)	SD	F	p
Hayes-Nance Maxilla Actual	Plaster model	40	71.35	72.00 (62.00;80.40)	4.06	0.076	0.927
	3D model		71.39	72.20 (63.30;80.40)	4.00		
	Rescanned 3D model		71.67	72.50 (63.80;80.50)	4.05		
Hayes-Nance Maxilla Required	Plaster model	40	72.71	72.75 (64.90;82.60)	4.00	0.027	0.973
	3D model		72.88	73.15 (65.20;81.90)	3.74		
	Rescanned 3D model		72.71	72.95 (64.70;80.10)	3.78		
Hayes-Nance Maxilla Discrepancy	Plaster model	40	–1.36	–1.80 (–14.40;9.70)	4.32	0.106	0.899
	3D model	40	–1.50	–1.50 (–12.10;9.00)	4.24		
	Rescanned 3D model	40	–1.06	–1.20 (–12.40;10.00)	4.29		
Hayes-Nance Mandible Actual	Plaster model	40	62.60	62.00 (55.00;72.50)	3.88	0.064	0.938
	3D model		62.54	62.15 (54.00;71.80)	3.86		
	Rescanned 3D model		62.83	62.60 (54.00;72.60)	3.81		
Hayes-Nance Mandible Required	Plaster model	40	63.73	63.50 (57.60;70.60)	3.78	0.029	0.971
	3D model		63.82	63.75 (56.30;69.60)	3.32		
	Rescanned 3D model		63.92	63.85 (56.10;70.60)	3.54		
Hayes-Nance Mandible Discrepancy	Plaster model	40	–0.93	–1.20 (–9.60;9.00)	4.29	0.077	0.926
	3D model		–1.29	–1.65 (–9.10;8.50)	3.87		
	Rescanned 3D model		–1.10	–2.15 (–8.90;9.30)	3.98		

n: number min: minimum max: maximum SD: standard deviation p: Statistical significance was set at $p<0.05$.

Table 2. Comparison of Bolton overall and anterior measurements.

	Group	n	Mean	Median (min;max)	SD	F	p
Bolton Overall Maxilla	Plaster model	40	92.62	92.65 (82.70;104.60)	5.02	0.107	0.899
	3D model		93.08	92.95 (82.90;103.10)	4.59		
	Rescanned 3D model		93.00	92.65 (82.30;102.30)	4.70		
Bolton Overall Mandible	Plaster model	40	85.10	85.35 (74.40;95.20)	5.11	0	1
	3D model		85.12	84.60 (74.70;94.00)	4.47		
	Rescanned 3D model		85.11	85.40 (74.30;94.90)	4.73		
Bolton Overall Discrepancy	Plaster model	40	–0.33	0.32 (–5.77;4.50)	2.89	0.655	0.521
	3D model		0.16	0.40 (–4.40;5.00)	2.33		
	Rescanned 3D model		0.31	0.30 (–5.30;6.00)	2.64		
Bolton Overall Ratio (%)	Plaster model	40	91.37	91.75 (86.32;96.29)	2.69	0.063	0.939
	3D model		91.54	91.67 (87.01;96.12)	2.36		
	Rescanned 3D model		91.54	91.63 (86.10;97.10)	2.35		
Bolton Anterior Maxilla	Plaster model	40	45.85	46.00 (39.80;51.70)	2.74	0.001	0.999
	3D model		45.83	46.10 (39.80;51.40)	2.63		
	Rescanned 3D model		45.82	46.15 (39.60;51.40)	2.67		
Bolton Anterior Mandible	Plaster model	40	36.28	36.25 (31.50;43.00)	2.43	0.182	0.834
	3D model		35.98	36.10 (31.40;40.90)	2.02		
	Rescanned 3D model		36.12	36.15 (31.60;41.30)	2.09		
Bolton Anterior Discrepancy	Plaster model	40	0.28	0.87 (–4.25;6.41)	2.44	0.923	0.400
	3D model		0.79	0.80 (–2.00;3.40)	1.40		
	Rescanned 3D model		0.73	1.05 (–3.50;3.40)	1.50		
Bolton Anterior Ratio (%)	Plaster model	40	79.13	78.92 (74.25;90.72)	3.21	1.386	0.254
	3D model		78.09	78.54 (70.03;83.19)	2.91		
	Rescanned 3D model		78.77	78.87 (74.10;84.55)	2.35		

n: number min: minimum max: maximum SD: standard deviation p: Statistical significance was set at $p<0.05$.

Table 3. Comparison of overjet and overbite measurements.

	Group	n	Mean	Median (min;max)	SD	F	p
Overbite	Plaster model		2.09	1.90 (–5.00;7.60)	2.25	0.195	0.823
	3D model	40	2.42	2.35 (–4.80;9.80)	2.72		
	Rescanned 3D model		2.21	2.20 (–5.00;7.60)	2.29		
Overjet	Plaster model		4.17	3.75 (0.00;8.50)	2.19	0.111	0.895
	3D model	40	4.01	3.85 (0.50;8.30)	2.30		
	Rescanned 3D model		4.24	3.75 (0.00;8.80)	2.29		

n: number min: minimum max: maximum SD: standard deviation p: Statistical significance was set at $p<0.05$.

Table 4. Intraclass correlation coefficients (ICC) and 95% confidence interval.

Variable	ICC	Lower Bound	Upper Bound	P-value
Hayes-Nance Maxilla Actual	0.998	0.996	0.999	0.0001
Hayes-Nance Maxilla Required	0.997	0.993	0.998	0.0001
Hayes-Nance Maxilla Discrepancy	0.996	0.993	0.998	0.0001
Hayes-Nance Mandible Actual	0.962	0.929	0.980	0.0001
Hayes-Nance Mandible Required	0.991	0.983	0.995	0.0001
Hayes-Nance Mandible Discrepancy	0.957	0.920	0.977	0.0001
Bolton Overall Maxilla	0.996	0.992	0.998	0.0001
Bolton Overall Mandible	0.996	0.992	0.998	0.0001
Bolton Overall Discrepancy	0.894	0.808	0.943	0.0001
Bolton Overall Ratio (%)	0.971	0.951	0.986	0.0001
Bolton Anterior Maxilla	0.996	0.992	0.998	0.0001
Bolton Anterior Mandible	0.908	0.831	0.951	0.0001
Bolton Anterior Discrepancy	0.812	0.672	0.897	0.0001
Bolton Anterior Ratio (%)	0.490	0.206	0.697	0.001
Overbite	0.756	0.580	0.865	0.0001
Overjet	0.932	0.873	0.964	0.0001

ICC: Intraclass Correlation Coefficient p: Statistical significance was set at $p<0.05$.

DISCUSSION

Intraoral digital impression systems provide improved accuracy and efficiency, offering a time-saving alternative to conventional methods and extraoral digitization of stone casts (14-16). Yılmaz *et al*. (11) compared the time taken for performing Bolton and Space analyses using digital models versus conventional plaster models, reporting that digital models reduced analysis time by 4.94 minutes compared to plaster models. In the present study, however, the focus shifted from time efficiency to evaluating the accuracy and validity of the models. A limitation of our study is the lack of time comparison for scanning and measurements due to its retrospective design; additionally, different clinicians performed the initial scans, as archival materials were used.

This study aimed to compare the sensitivity of digital and conventional measurements in terms of space discrepancies, tooth size analyses, and overjet and overbite values. It also investigates whether the sensitivity of plaster models is preserved when scanned with an intraoral scanner. By comparing rescanned plaster models and digital models, along with utilizing various analysis methods, the study intends to contribute valuable insights to the literature. Additionally, to enhance the reliability of the methodology, models were selected from individuals in permanent dentition to address concerns regarding the consistency of space analysis and other measurements in primary dentition. Since no significant difference was found among the methods, the null hypothesis was not rejected.

Keating *et al*. (17) evaluated the accuracy and reproducibility of a 3D optical laser-scanning device (Konica Minolta Inc., Tokyo, Japan) for capturing the surface details of plaster study models and assessed the precision of physical

model replicas produced from these digital files. In the current study, an accessible intraoral optical scanner was employed instead, demonstrating the growing trend towards using intraoral devices for digital model acquisition in orthodontics. Amuk *et al*. (18) compared dental measurements across conventional plaster models, digital models obtained through impression scanning, and plaster model scanning, finding no significant differences among the three methods. In the present study, we utilized an intraoral scanner instead of a model scanner, prioritizing accessibility and clinical need. Our results corroborate those of Amuk *et al*. (18), showing no significant differences among the methods. Flügge *et al*. (12) compared the extraoral digitization of plaster models using two scanners (iTero; Align Technologies, San Jose, Calif and D250; 3Shape, Copenhagen, Denmark), performing intraoral and model scanning 10 times with each device, and found that intraoral scanning was less accurate than model scanning, and that the iTero was less accurate than the 3Shape—suggesting that intraoral conditions such as saliva and limited space may contribute to reduced accuracy. In contrast, the current study used a single scanner for digitalization, with a large number of models scanned only once each, which likely contributed to the differing results. Suryajaya *et al*. (7) assessed the linear accuracy and Bolton analysis of digital dental models scanned using Trios (3Shape, Copenhagen, Denmark) and resin models printed with Formlabs 2 (Formlabs, Somerville, MA), comparing them to conventional plaster models, while Watanabe-Kanno *et al*. (13) similarly compared plaster and digital dental models in determining tooth-size discrepancies and Bolton analysis. In the current study, both the anterior and overall Bolton analyses were compared across all three methods, and no significant differences were observed, consistent with these previous findings, suggesting that digital and plaster models can be used interchangeably for Bolton analysis without compromising accuracy.

In a study by Leifert *et al*. (10), 25 plaster casts and 3D orthodontic models were evaluated for space analysis using OrthoCAD software (OrthoCad, Cadent, Fairview, NJ), similar to the software used in our study; their findings indicated that the software's accuracy was clinically acceptable. A statistically significant difference was found between plaster and digital models in the maxillary arch space analysis, though no significant difference was found in the mandibular arch. In the current study, no differences were found among space analyses in either arch, and no analysis included arch form. The software selected for the present study was likewise chosen for its accessibility and user-friendliness, ensuring ease of use in clinical practice.

In the study by Watanabe-Kanno *et al*. (13), two examiners independently calculated measurements for space availability, required space, and Bolton ratios. While the first examiner found statistically significant differences in some variables—including the anterior and overall Bolton ratios—the second examiner did not observe any significant differences, an inter-examiner variability also reported in other studies evaluating digital and plaster models (7,17). In our study, no significant differences were found.

Several previous studies have compared plaster and digital models in terms of accuracy and authenticity, with some reporting statistical differences (11,12) and others finding no clinically significant differences (5,13). In our current study, no statistically significant difference was found between digital and conventional methods for Hayes-Nance, Bolton analysis, and overjet/overbite values across digital, conventional, and extraoral digitization of stone casts. It is important to distinguish between statistical and clinical significance: although no statistically significant differences were found among the three methods, for most parameters the mean differences between groups

were less than 1 mm, generally accepted as within the clinically acceptable range for orthodontic model analysis. However, for variables with moderate intra-examiner reliability, such as Bolton Anterior Ratio and Overbite, greater caution is warranted. The present study adds to the existing literature by specifically investigating the use of an intraoral scanner—a device primarily designed for direct oral scanning—for the digitization of plaster models, representing a practically relevant clinical scenario. Unlike most previous comparisons that utilized dedicated model scanners (11,12,18), our study demonstrates that intraoral scanners may serve as a viable and accessible alternative for digitizing plaster models in settings where dedicated scanners are unavailable. This distinction represents the primary contribution of the present study in bridging an existing gap in the literature.

Rossini *et al*. (19) reviewed the literature between 2000 and 2014 to assess the accuracy, validity, and reliability of measurements from digital dental study models compared with traditional plaster models, confirming that digital models are comparable to plaster models in these respects. They noted that the primary limitation of digital models lies in landmark identification rather than the measuring device or software itself, and highlighted the cost-effectiveness, time efficiency, and space-saving advantages that position digital models as a potential new standard in contemporary orthodontic practice. In our study, we selected a widely accessible scanner and software to facilitate ease of use in clinical practice, and our findings indicate that the results obtained using this digital technology were as reliable as those from traditional methods—highlighting the potential of digital models as a feasible and efficient alternative to plaster models.

Recent evidence has further supported the validity of digital orthodontic measurements across different clinical settings and patient populations. Nelwan *et al*. (20) evaluated space analysis measurements obtained conventionally and digitally in the mixed dentition phase using Moyer's analysis and found no significant difference between the two methods, extending the applicability of these findings beyond the permanent dentition population examined in our study. Similarly, in a systematic review and meta-analysis pooling data from multiple studies comparing direct plaster model measurements with digital models obtained via laboratory scanners, Warnecki *et al*. (21) reported no statistically significant differences for intermolar width, intercanine width, overjet, or overbite; however, substantial heterogeneity was observed among the included studies, and four investigations reported differences that could be considered clinically significant. These findings support our interpretation that statistical equivalence should not automatically be interpreted as clinical equivalence. Alassiry (22), in a systematic review on the clinical aspects of digital three-dimensional intraoral scanning in orthodontics, similarly noted that the accuracy of intraoral scanners compared to conventional impression techniques remains controversial in the literature, while concluding that digital scanning offers satisfactory to excellent reproducibility, shorter scanning time, and improved patient comfort, rendering it sufficiently accurate for treatment planning and clinical use.

As documented in the literature, the clinical use of digital model analysis is acceptable and yields highly accurate results. There is a need for future studies evaluating 3D printed models, which have recently become popular, along with formal time-efficiency analyses.

CONCLUSION

Within the limitations of this retrospective comparative study, no statistically significant differences were found between digital models, plaster models, and digitally scanned plaster models for Hayes-Nance, Bolton, overjet, and overbite analyses. These findings suggest that the three methods

may offer comparable results in clinical practice; however, the interchangeable use of these models should be interpreted with caution, particularly given the moderate intra-examiner reliability observed for Bolton Anterior Ratio, Bolton Anterior Discrepancy, and Overbite. Scanning plaster models with an intraoral scanner appears to be a feasible alternative to direct digital scanning, though further studies with larger and more diverse samples are needed to confirm these findings and establish their broader clinical applicability.

STATEMENTS

AUTHOR CONTRIBUTION STATEMENT: Conceptualization and Design, M.K., S.B., D.S. and İ.S.; Literature Review, D.S. and İ.S..; Methodology and Validation, M.K., S.B., D.S. and İ.S.; Formal Analysis, M.K., S.B., D.S. and İ.S.; Investigation and Data Collection, D.S. and İ.S.; Resources, D.S. and İ.S.; Data Analysis and Interpretation, M.K., D.S. and İ.S.; Writing – Original Draft Preparation, M.K., D.S. and İ.S.; Writing – Review & Editing, M.K., D.S. and İ.S.; Supervision, M.K. and S.B.; Project Administration, M.K. and S.B. The authors received no funding for this study.

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