IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 24, Issue 6 Ser. 3 (June. 2025), PP 39-44
www.iosrjournals.org

Gnathometric Analysis On Conventional Plaster Models And Digital Models-A Comparative Study

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Abstract:
Background: *In everyday orthodontic practice, studio models are the most important component in diagnosis and treatment planning. Nowadays plaster models represent a gold standard that serves to implement various orthodontic measurements and analyzes. With the advancement of technology, digital models represent an alternative that allows three-dimensional representation of teeth and dental relationships. This study describes plaster and digital models with their advantages and disadvantages, dental arch analysis, Bolton analysis, and the time needed for analysis.The aim of this study is to compare the gnathometric analysis of teeth and dental arches using conventional plaster models and digital models, particularly in terms of accuracy, time efficiency, and reliability of the analyses*
Materials and Methods: *Gnathometric analysis was performed on plaster models of 60 patients aged 13–18 years with dental crowding. These models were then scanned using the 3Shape D800™ scanner and analyzed with 3Shape OrthoAnalyzer™ software. The collected data were statistically processed, presented in tables and graphs, and descriptively analyzed.*
Results: *Digital models offer a high degree of validity, as all differences in measurements between the methods are clinically acceptable. Additionally, digital models significantly reduce the time required for analyzing of predefined parameters*
Conclusion: *These findings suggest that digital models represent a valid alternative to conventional plaster models in orthodontic diagnostics.*
Key Word: *gnathometric analysis, plaster models, digital models.*

Date of Submission: 27-05-2025 Date of Acceptance: 07-06-2025

I. Introduction

Accurate diagnosis and treatment planning are essential components of everyday orthodontic practice. In addition to clinical examinations, orthopantomographic and cephalometric radiographs, study models remain an indispensable part of orthodontic diagnostics. The morphological analysis of study models is one of the fundamental aspects of orthodontic diagnosis. Plaster models are still considered the "gold standard" in diagnosing of orthodontic anomalies. These models provide a three-dimensional view of the patient's occlusion, reliably reproducing the morphological details of the impression area while depicting the shape of the palate, dental arch, and alveolar base, as well as the position and shape of the teeth and any deviations in the sagittal, transverse, and medial planes. These planes are of great importance throughout the entire morphological analysis. Measurements are taken based on them, and the obtained values are compared with average values to establish a morphological orthodontic diagnosis.[1]

Beyond morphological analysis, which is imperative for orthodontic diagnosis and treatment planning, orthodontic study plaster models serve additional purposes. They are used in the fabrication of orthodontic appliances, monitoring patient growth and development, and as part of medical documentation. Digital technology has brought significant changes to the way orthodontic records are taken and stored. With the introduction of digital study models, orthodontists now have an alternative to traditional plaster models. [2]

Digital study models represent a reliable replacement for traditional plaster models. Their advantages in orthodontic diagnosis and treatment include the rapid and easy electronic transfer of data, quick access, and reduced storage space requirements. Digital models can be virtually manipulated, allowing for detailed analysis of specific teeth, the shape of dental arches, the degree of crowding or spacing, and the type of malocclusion. Commercially available digital models can be obtained using either direct or indirect methods.[3] Several studies indicate that measurements of dental arch width and Bolton analysis performed on digital models are more valid and productive compared to plaster models.[4]

Given the conflicting results from various studies, the need to further investigate this topic has arisen. This study aims is to compare the measurements obtained through both methods to assess whether digital models can replace traditional plaster models in orthodontic practice.

II. Material And Methods

The study included plaster models from 60 patients with dental crowding, aged 13-18 years, which were subsequently scanned with the 3Shape D800™ scanner and analyzed using 3Shape Ortho Analyzer ™ software. Inclusion criteria for the study were models from patients with crowding in the dental arches, with complete eruption of permanent teeth and no previous orthodontic treatment. Measurements were conducted in three directions: transversal, sagittal, and vertical, applying the Harper method.

The following parameters were analyzed: width, length, height, Bolton Index and time required for analysis. With the help of a digital caliper - Extol premium (figure.1) and orthodontic measuring instruments (orthometer) by Korkhaus (figure.2), the following measurements were conducted on each plaster model.

Figure 1. digital caliper - Extol premium

Figure 2. orthometer by Korkhaus

Width of the dental arches (WDA) were performed at three levels for each dental arch according to Harper: Intercanine width – measured as the distance between the cusps of the canines in the maxillary and mandibular dental arch. Interpremolar width – measured as the distance between the buccal cusps of the first and second premolars in both dental arches. Intermolar width – measured as the distance between the distobuccal cusps of the first permanent molars in both dental arches. (figure.3a)

Length of the dental arches according to Harper - measured as the distance between the distal surface of the first permanent molar and the contact point between the central incisors, separately for the left and right side in both dental arches. (figure.3b)

Height of the dental arches according to Harper - measured as the distance between the distal surfaces of the first permanent molars and the incisal edge of the central incisors, following the linea mediana. (figure.3c)

Bolton's analysis of dental harmony - measured as the sum of the mesiodistal widths of 6 and 12 permanent teeth. In this analysis, the mesiodistal widths of twelve teeth were measured, starting from the central incisors to the first permanent molar in the maxillary and mandibular dental arches. These widths were then summed and entered into Bolton's equation (cited in Marković)[5] to determine the index for our subjects. (figure.3d)

Time required for measurements was also compared. For both types of orthodontic models, the start of measurement was determined by a stopwatch, from the moment the models were placed before the operator, and stopped when all measurements were completed.

Next, the same plaster models were scanned using the 3Shape D800™ scanner, and then, using the 3Shape OrthoAnalyzer™ software , the same gnathometric analysis was performed as was done directly on the plaster models (figure.4). Additionally, a detailed statistical analysis was conducted using SPSS software, version 22.0, applying the Mann-Whitney U test and the t-test for independent samples. The distribution of frequencies of numerical variables was determined using the Shapiro-Wilk W test. To determine statistical significance, two-way tests were used, with a significance level of $p<0.05$.

(a) (b) (c) (d)

Figure.3. measurment made on plaster models for: a) interpremolar width for second premolar upper according to Harper, b) length of the dental arch according to Harper, c) height of the dental arch according to Harper, d)mesiodistal widths of twelve teeth for Bolton's analysis

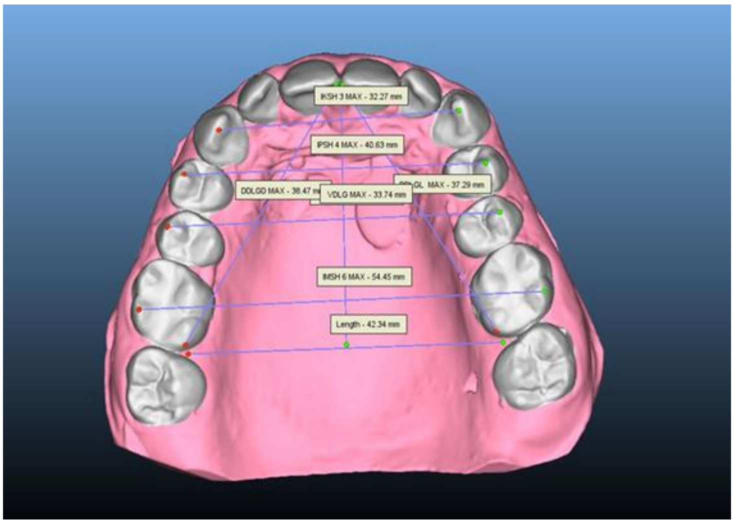

Figure 4. Digital model- placed points for measurement of (ICWU), (IPWU4), (IPWU5), (IMWU), (LDA), (HAD).

III. Result

This study was a prospective controlled comparative clinical study conducted during the 2023/2024 period at the Clinic of Orthodontics within the University Dental Clinical Center "St. Panteleimon" in Skopje. The study included orthodontic plaster study models from 60 patients (100%), aged 13–18 years. The sample was divided into two groups: group A: gnathometric analyses obtained using conventional plaster models (60 analyses; 50%) and group B: gnathometric analyses obtained using digital models (60 analyses; 50%).

Within the study, a comparison was made of the width of the dental arches (WDA) obtained through measurements with the conventional and digital models. Measurements in the transverse direction were performed at three levels for each dental arch according to Harper. The analysis was conducted for: a) Intercanine width upper (ICWU) and lower (ICWL); b)Interpremolar width for the first premolar upper (IPWU4) and lower (IPWL4); c)Interpremolar width for the second premolar upper (IPWU5) and lower (IPWL5); d)Intermolar width upper

(IMWU) and lower (IMWL). Comparison of WDA from the conventional and digital model showed that there is no significant difference between the dimensions of: ICWU (p=0.6311), IPWU4 (p=0.8357), IPWU5 (p=0.5602), IMWU (p=0.4493), ICWL (p=0.4357), IPWL4 (p=0.5826), IPWL5 (p=0.5310), IMWL (p=0.4029). *(table1)*

Table no 1:. Comparison of (WDA) between conventional and digital measurement

(WDA)	(Mean)	(N)	(Std. Deviation)	(Min)	(Max)	Percentiles		
						25th	50th (Median)	75th
ICWU - Mann-Whitney U Test: Z=-0,4802; p=0,6311								
conventional	32,74	60	2,10	29,2	37,1	31,1	32,4	33,9
digital	32,84	60	1,98	28,8	37,7	31,4	32,6	34,2
IPWU4 - Mann-Whitney U Test: Z=0,2073; p=0,8357								
conventional	39,59	60	4,75	33,2	68,1	37,2	38,8	41,0

digital	38,99	60	2,78	32,4	46,8	37,1	38,8	40,9
IPWU5 - Mann-Whitney U Test: Z=-0,5826; p=0,5602								
conventional	43,90	60	3,01	37,2	50,1	41,3	44,1	46,1
digital	44,59	60	4,82	36,6	73,1	41,5	44,3	46,7
IMWU - Inependent t-test for two samples: t (118)=-0,7591; p=0,4493								
conventional	51,67	60	2,52	46,0	57,9	50,1	51,6	53,3
digital	52,03	60	2,63	44,9	58,9	50,5	52,00	53,8
ICWL - Mann-Whitney U Test: Z=-0,7794; p=0,4357								
conventional	24,77	60	1,98	18,8	28,5	23,3	25,0	25,9
digital	25,57	60	4,61	19,1	57,1	23,7	25,1	26,4
IPWL4 - Inependent t-test for two samples: t (118)=-0,5511; p=0,5826								
conventional	32,08	60	2,29	26,1	38,9	30,7	32,1	33,5
digital	32,32	60	2,41	26,3	37,9	30,6	32,4	33,7
IPWL5 - Inependent t-test for two samples: t (118)=-0,6283; p=0,5310								
conventional	37,91	60	2,62	32,6	43,8	35,8	38,1	39,9
digital	38,21	60	2,58	32,6	44,0	36,5	38,3	40,0
IMWL - Inependent t-test for two samples: t (118)=-0,8395; p=0,4029								
conventional	46,51	60	2,63	40,8	52,4	44,9	46,8	47,9
digital	46,91	60	2,62	40,8	52,6	45,2	47,0	48,9

The analysis of LDA covered the following measurements: a) llength of the dental arch upper right – LDAUR. b) length of the dental arch upper left – LDAUL. c) length of the dental arch lower right – LDALR; d) length of the dental arch lower left – LDALL. By comparison of the values for the length of the dental arch (LDA) obtained using the conventional and digital model the results showed that exists significant difference between LDAUR (p=0.0005), LDAUL (p=0.0006), LDALR (p=0.0008) and LDALL (p=0.0001) in both models, favoring significantly smaller dimensions obtained with the digital model. *(table2)*

Table no 2: Comparison of (LDA) between conventional and digital measurement

LDA	(Mean)	(N)	(Std. Deviation)	(Min)	(Max)	Percentiles		
						25th	50th (Median)	75th
LDAUR - Inependent t-test for two samples: t (118)=3,5651; p=0,0005*								
conventional	43,95	60	2,05	38,3	49,5	42,4	43,9	45,3
digital	42,58	60	2,18	37,7	48,3	40,7	42,6	43,9
LDAUL - Mann-Whitney U Test: Z=3,4142; p=0,0006*								
conventional	44,30	60	2,57	40,6	57,7	42,8	43,9	45,4
digital	42,92	60	2,80	38,5	57,0	41,10	42,9	44,0
LDALR - Inependent t-test for two samples: t (118)=3,4306; p=0,0008*								
conventional	39,53	60	2,41	33,1	47,5	38,0	39,8	40,9
digital	38,08	60	2,24	30,6	42,3	36,7	38,2	39,7
LDALL- Inependent t-test for two samples: t (118)=4,0141; p=0,0001*								
conventional	39,46	60	1,97	35,1	42,7	38,2	39,7	40,9
digital	38,08	60	1,79	33,9	42,7	36,8	38,4	39,3

The analysis of the height of the dental arches, was made on conventional and digital models for the upper dental arch (HDAU) and for the lower dental arch (HDAL).The results showed a significant difference between HDAU (p=0.0002) and (HDAL) (p=0.0003) values obtained with both models, favoring significantly larger dimensions obtained with the digital model. *(table3).*

Table no 3: **Comparison of (HDA) between conventional and digital measurement**

HDA	(Mean)	(N)	(Std. Deviation)	(Min)	(Max)	Percentiles		
						25th	50th (Median)	75th
HDAU - Mann-Whitney U Test: Z=-3,6898; p=0,0002*								
conventional	39,05	60	2,52	32,0	49,5	38,0	39,0	40,0
digital	40,63	60	2,69	33,5	51,7	38,9	40,7	41,8
HDAL - Inependent t-test for two samples: t (118)=-3,6836; p=0,0003								
conventional	33,56	60	2,11	28,5	38,5	32,5	33,5	35,0
digital	35,02	60	2,23	29,7	40,4	33,3	35,2	36,4

The measurements made on the plaster and digital model for the Antrerior Bolton and Total Bolton ratio, didn't show significant difference between the values of Anterior Bolton (p=0.6595) *(table4)* and Total Bolton (p=0.2775) *(table5).*

Table no 4: Comparison of Anterior Bolton ration between conventional and digital measurement

Anterior Bolton	(Mean)	(N)	(Std. Deviation)	(Min)	(Max)	Percentiles		
						25th	50th (Median)	75th
Inependent t-test for two samples: t (118)=-0,4416; p=0,6595								
conventional	78,51	60	3,38	71,4	86,7	75,8	78,5	80,7
digital	78,81	60	4,05	70,0	86,9	75,7	78,6	81,4

Table no 5. Comparison of Total Bolton ration between conventional and digital measurement

Total Bolton	(Mean)	(N)	(Std. Deviation)	(Min)	(Max)	Percentiles		
						25th	50th (Median)	75th
Inependent t-test for two samples: t (118)=-1,0911; p=0,2775								
conventional	91,90	60	2,62	86,6	99,1	90,3	91,7	93,3
digital	92,46	60	3,05	83,6	98,5	90,4	92,5	94,7

The average time required to perform the gnathometric analysis with the conventional model was 18.1±4.7 min. while with the digital model, it was 11.7±1.6 min. For that, a statistically significant difference was observed between the time required to perform the gnathometric analysis with the conventional and digital models, in favor of a significantly shorter time required with the digital model (p=0.00001) *(Table 6).*

Table no 6: Comparison of time required for gnathometric analysis according to conventional and digital model

Time (minutes)	(Mean)	(N)	(Std. Deviation)	(Min)	(Max)	Percentiles		
						25th	50th (Median)	75th
Mann-Whitney U Test: Z=8,9962p=0,00001*								
conventional	18,12	60	4,69	12,4	40,1	15,4	16,90	19,8
digital	11,66	60	1,6	9,1	15,6	10,3	11,5	12,4

IV. Discussion

The comparison of the width of the dental arch in this study, conducted in the region of the canines, first and second premolars, as well as first molars, both in the upper and lower jaw, showed that, there was no significant difference between the dimensions of the dental arch widths obtained with both models. Contrary to these results, in the study by Watanabe-Kanno et al.[6], the values for intercanine and intermolar widths in plaster models were slightly higher compared to digital models. Watanabe-Kanno et al.[6] stated that if the interproximal surface between the teeth is not clearly defined when marking the points, this may lead to changes in the reproducibility of the measurements.

In the analysis of the length of the dental arch, for p<0.05, a statistically significant difference was observed between the dimensions of the dental arch length obtained with the conventional and digital models, favoring significantly smaller dimensions obtained with the digital model. Schirmer and Wiltshire[7] conducted a study to determine whether differences exist between manual and computer-designed space analysis. Manual measurements were taken using a digital caliper, while for digital measurements, photocopies of the plaster models were made and subsequently digitized. The differences between manual and digital measurements were significant. For the length measurements of the maxillary arch, the average difference was 4.7mm, and for the mandibular arch, it was 3.1mm.When comparing the height measurements of the maxillary arch, for p<0.05, a significant difference was observed between the conventional and digital models, favoring significantly larger dimensions obtained with the digital model in the upper (p=0.0002) and lower (p=0.0003) arches.

The results of this study confirm the accuracy and reliability of the Bolton index calculated using both digital and plaster models. That is, no statistically significant differences were found in the values of the anterior and total Bolton analysis performed on plaster and digital models. Similar results to our study were found by Nalcaci et al.[8], who reported that Bolton analysis conducted on Ortho 3D models (O3DM, ORTHOLAB, Sp,ZO.O., Czestochowa, Poland) can be used with confidence in clinical practice. This study is the first to confirm the clinical accuracy of Bolton analysis using the Ortho Insight 3D system.

In this study, significant differences were observed in the time required to perform the analysis. For p<0.05 (p=0.00001), a statistically significant difference was observed, favoring significantly shorter time with the application of the digital model. The time required to complete measurements on study models is important for effective orthodontic care. Similar results were obtained by Reuschl et.al.[9], where the time required for orthodontic measurements was statistically lower for digital models compared to manual models ($P \leq 0.0001$). This could be a decisive criterion in choosing a procedure in daily orthodontic practice. The estimated time saved is approximately 2 minutes per model.

In this study, several parameters showed significant differences between manual and digital measurements. This may be due to fundamental differences between the two methods, as digital measurement provides a three-dimensional view that allows for better positioning of reference points and includes digital tools for measuring diameters and distances along selected planes.

Digital models have the potential to become a routine tool in orthodontic diagnosis primarily due to their efficiency in reducing the time required for analysis, their precision, resistance to degradation, minimal storage space requirements, and easy of data transfer. The only proven disadvantage is their economic feasibility, as they require higher costs and more time to refine the working system. Plaster models are still the gold standard in orthodontics due to their ease of fabrication, precision, and economic feasibility. However, despite these advantages, plaster models also present certain disadvantages, such as the storage space required for preservation, their susceptibility to fractures and damage, and the difficulties in transportation. With all these advantages and minor limitations, and with the increasing availability of digital systems, they show a tendency toward greater prevalence as one of the tools for diagnosis in orthodontic practice.

V. Conclusion

In the comparative study of gnathometric analysis between conventional plaster models and digital models, we concluded that digital models offer a high level of validity, meaning all differences in measurements between methods are clinically acceptable.

From this, it follows that digital models represent a reliable alternative to conventional plaster models, which are accurate, efficient, easy to use, and allow for visualization of planned treatment outcomes. By achieving the set goal, with the results obtained in our study, we will contribute to clarifying the ability of digital models to offer greater efficiency and convenience for orthodontists compared to traditional plaster models, thereby stimulating faster and broader adoption of this technology in orthodontic offices.

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