

## Conventional Versus Digital Assessment of Dental Arches' Perimeters in Mixed Dentition

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**Abstract:** The advances of digital technologies in dentistry have made significant changes in orthodontic diagnosis and treatment planning. Digital three-dimensional models are commonly used to perform dental arch and teeth measurements through intra-oral scanners and software. This study aimed to test the reliability of two softwares in measuring dental arch perimeters compared to the conventional one. Twenty-four pairs of stone models belonging to Iraqi children at the mixed dentition stage were selected and scanned with a laser scanner. Maxillary and mandibular dental arch perimeters were measured as a sum of four segments from central incisor to canine and from canine to the first molar on both sides using digital calipers (on stone models) Ortho Analyzer, and the Geomagic Design X software (on scanned models). Reliability has been evaluated by intra-class correlation coefficient and Bland-Altman plots, while systematic and proportional biases were evaluated by paired sample t-test and linear regression analysis, respectively. Non-significant differences were obtained for most measurements with good to excellent reliability. Digital technologies, including model scanning and software measurements can be used with adequate precision and reliability to assess dental arch perimeters as with stone models and conventional measurements with dental vernier.

**Keywords:** arch perimeter, digital measurements, scanner, orthodontics, study models.

### 混合牙列中牙弓周長的傳統與數字評估

**摘要：**牙科數字技術的進步使正畸診斷和治療計劃發生了重大變化。數字三維模型通常用於通過口內掃描儀和軟件進行牙弓和牙齒測量。本研究旨在與傳統軟件相比，測試兩種軟件在測量牙弓周長方面的可靠性。選擇了24對屬於混合牙列階段伊拉克兒童的石頭模型，並用激光掃描儀掃描。使用數字卡尺（在石頭模型上）正交分析儀和地磁設計X軟件（在掃描模型上）測量上頰和下頰牙弓周長作為從中切牙到尖牙以及從尖牙到兩側第一磨牙的四個部分的總和。可靠性已通過類內相關係數和Bland-Altman圖進行評估，而系統偏差和比例偏差分別通過配對樣本t檢驗和線性回歸分析進行評估。對於大多數具有良好至極好可靠性的測量，獲得了非顯著差異。包括模型掃描和軟件測量在內的數字技術可以以足夠的精度和可靠性用於評估牙弓周長，就像使用石頭模型和使用牙科游標進行常規測量一樣。

**关键词：**足弓周長、數字測量、掃描儀、正畸、研究模型。

## 1. Introduction

Dental measurements are of great importance in

dentistry generally and at specific consideration in orthodontic diagnosis and planning proper treatment. The old plaster models have a long history used as

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diagnostic aids to visualize teeth position and morphology in the corresponding dental arches, besides providing a 3D patient occlusion model [1, 2].

However, this type of model has some disadvantages related to volumetric deformation, leading to errors and the possibility of damage during storage and transportation. Nowadays, digitization of the models allows the assessment of vertical, horizontal, and sagittal planes with nearly real approximation [3, 4].

Compared to the plaster models, the digital model has some advantages like the ease of transportability with the ability to be sent instantly through email, enhancing the cooperation with other specialists. Apart from their advantages, physical cast replication is unnecessary, saving time and materials and offering a suitable digital substitution for model archival [5, 6].

Several studies have assessed the accuracy and reliability of digital model measurements that have been made with the plaster models scan. Some of those researches did not show any statistical differences between measurements that have been made on the digital and the stone models [6-8], whereas other researches have discovered statistically significant differences between plaster and digital models; however, those differences have been considered irrelevant clinically [9-11].

On the other hand, some studies found that measurements on digital models had significantly larger [5, 12-15] or lower values for the measurements compared to the plaster models [9, 16], but this difference was clinically negligible. So, in conclusion, diagnoses and treatment decisions do not have a statistical difference when utilizing digital models instead of stone [17].

This study aimed to test the reliability of different software in measuring dental arch perimeters at mixed dentition using scanned models compared to the conventional method on plaster models.

## 2. Methods

Scientific and ethical committees have approved the College of Dentistry, Mustansiriyah University study.

The samples of this retrospective study consisted of 24 pairs of stone models obtained from 24 Iraqi children aged 8-9 years at the mixed dentition stage (12 males and 12 females) selected from different primary schools. The samples were retrieved from the archives of the POP department at the College of Dentistry, Mustansiriyah University.

The inclusion criteria of the selected samples included the presence of all the permanent first molars, central and lateral incisors, deciduous canines, the first and second deciduous molars.

The exclusion criteria included the presence of any syndrome or craniofacial malformation or obvious facial asymmetry, history of orthodontic treatment or space maintenance, presence of visually apparent interproximal caries, history of a primary molar or canine extractions, restorations or fractures that included the incisal edges of the permanent central incisors, digit habits past the age of 3 years, ectopically erupting first molars. Models with defects, voids, and fractures were also excluded.

The stone models were scanned using a 3D lab scanner D700 from 3Shape Co., Copenhagen, Denmark. Then dental arch perimeters were assessed on the stone models (Fig. 1) using a digital caliper to the nearest 0.01 mm (Insize Co., USA), whereas on the scanned models, an assessment was done using two different software (Fig. 2 and 3) namely, Orthoanalyzerprogram (3Shape, Copenhagen, Denmark) and the Geomagic design X program (CAD MicroSolution, Morrisville, USA). Single operator with experience of 18 years performed the measurements on a base of six pairs of models per day.

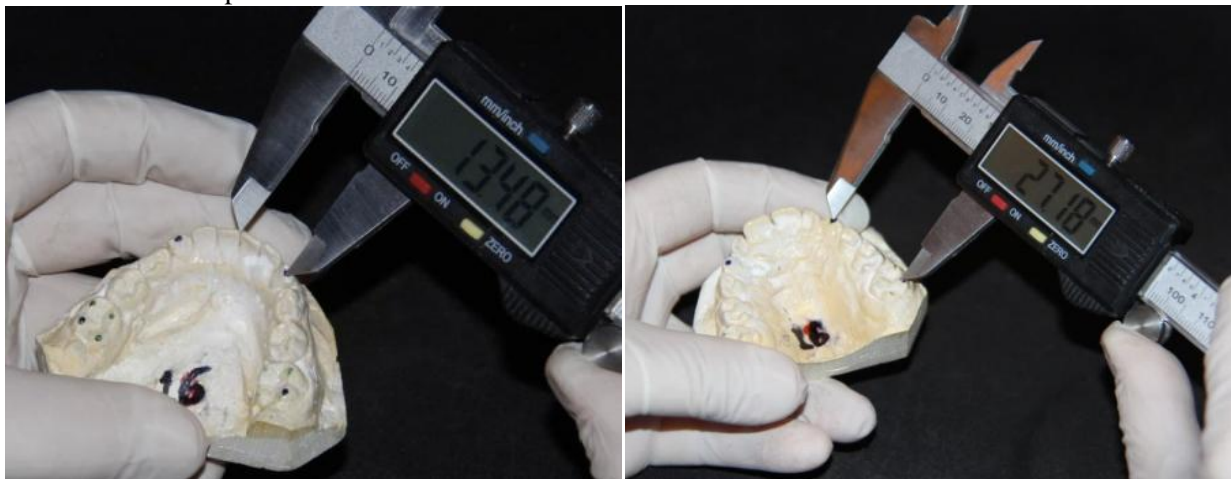


Fig. 1 Measuring arch perimeter on stone models using digital vernier

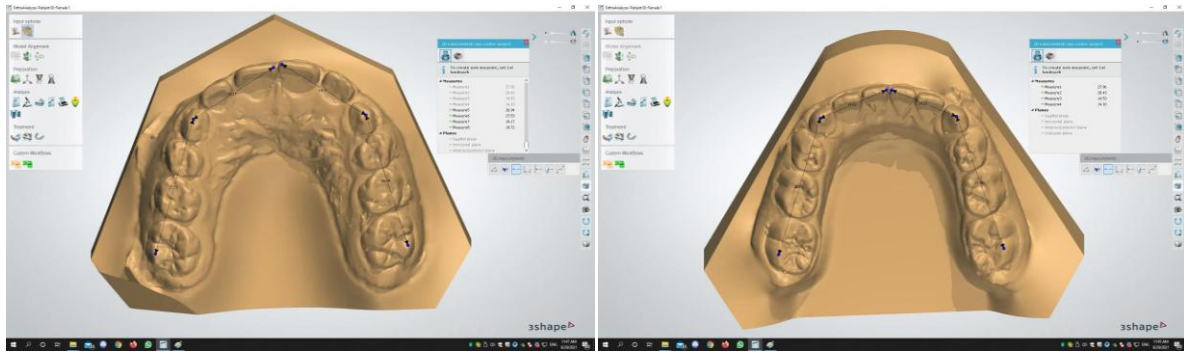


Fig. 2 Measuring arch perimeter on scanned models using Orthoanalyzer software

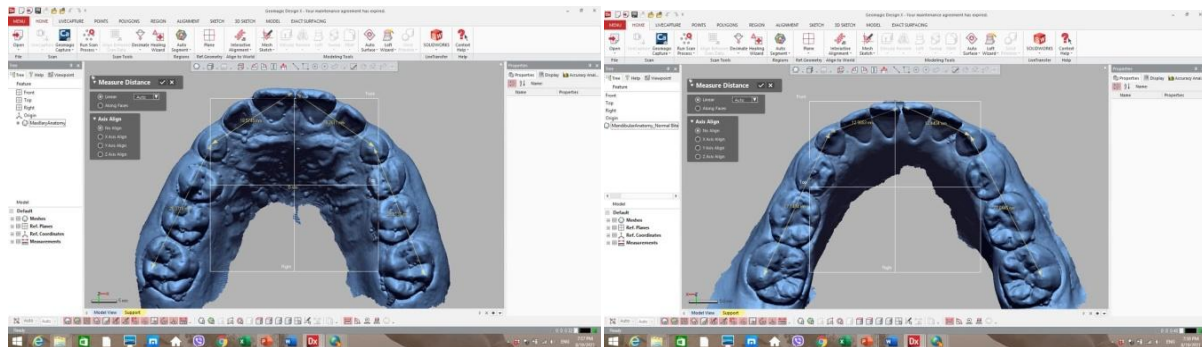


Fig. 3 Measuring arch perimeter on scanned models using Geomagic design X software

The dental arch perimeter was assessed for every arch by summation of four segments [18] representing the right and left linear distances from the mesial contact point of permanent central incisors to primary canine cusp tips (representing the incisal-canine distance, INCD) and from their tips to distobuccal cusp tips of 1<sup>st</sup> permanent molars (representing the canine-molar distance, CMD).

A clinically pertinent difference was determined when the difference in the linear measurements was greater than 2 mm [20].

Statistical analyses were performed using SPSS v. 25 (IBM, Chicago, USA), including the means and standard deviations. The reliability was tested by Bland-Altman plots and intra-class correlation coefficient (ICC), and the systematic and proportional biases were tested by paired sample t-test and linear regression analysis, respectively. The probability value was set at 0.05. Interpretation of the ICC test is as follows [19]:

- ICC < 0.50, indicative of poor reliability

- ICC = 0.50-0.75, moderate reliability
- ICC = 0.75-0.90, good reliability
- ICC > 0.90, excellent reliability

### 3. Results

In order to test the intra-operator reliability, the linear distances were re-measured on five pairs of models for each method, and the results indicated excellent reliability (ICC = 0.96 for the manual, 0.929 for the 3Shape Orthoanalyzer, and 0.94 for Geomagic Design X software).

Table 1 demonstrated the descriptive statistics of the maxillary and mandibular dental arch segments and perimeters measured using dental vernier directly on stone models and 3Shape software for the scanned models. Generally, the mean values of the right and left central incisor-canine distances were higher in the vernier group and just the reverse for the canine-molar distances.

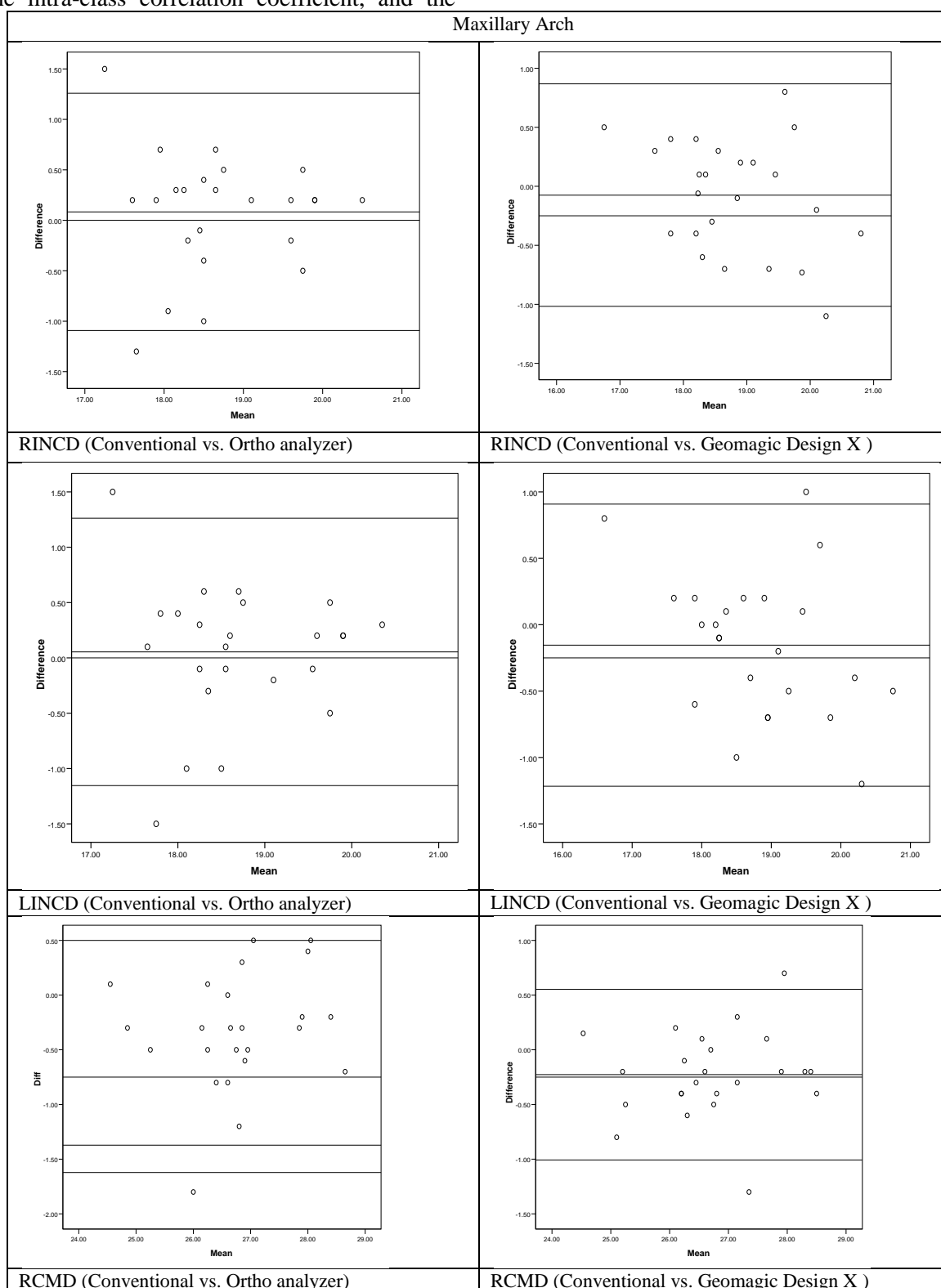
Table 1 Descriptive statistics, method difference, reliability, and linear regression test between the vernier and Ortho Analyzer method

Arch	Measurements	Descriptive statistics				Method difference			Reliability	Regression			
		Vernier		Ortho Analyzer		Mean difference	t-test	p-value		ICC	B	SE.	t-test
		Mean	SD.	Mean	SD.								
Maxillary	RINCD	18.758	0.904	18.675	0.917	0.083	0.681	0.503	0.783	-0.015	0.149	-0.104	0.918
	LINCD	18.746	0.891	18.692	0.889	0.054	0.430	0.671	0.760	0.003	0.157	0.020	0.984
	RCMD	26.608	1.113	26.938	1.020	-0.329	-3.031	0.006	0.876	0.092	0.108	0.856	0.401
	LCMD	26.600	1.129	26.950	1.027	-0.350	-3.240	0.004	0.880	0.101	0.106	0.955	0.350
	Arch perimeter	90.713	3.239	91.254	2.863	-0.542	-1.354	0.189	0.800	0.137	0.141	0.969	0.343
Mandibular	RINCD	14.042	0.750	13.908	0.828	0.133	2.041	0.053	0.918	-0.103	0.085	-1.201	0.242
	LINCD	14.058	0.753	13.900	0.863	0.158	1.974	0.061	0.883	-0.145	0.077	-1.881	0.073
	RCMD	27.727	0.880	27.979	1.002	-0.252	-1.850	0.077	0.794	-0.148	0.159	-0.932	0.362
	LCMD	27.700	0.845	27.988	0.990	-0.287	-2.076	0.049	0.782	-0.181	0.165	-1.102	0.282
	Arch perimeter	83.526	2.549	83.817	2.930	-0.290	-0.912	0.371	0.839	-0.151	0.122	-1.231	0.231

Systematic bias was determined by paired sample t-test (as the data were normally distributed after the Shapiro-Wilk test). Only the right and the left canine-molar distances in the maxillary arch and left canine-molar distance in the mandibular arch showed significant differences, although the mean difference was not exceeding 0.35 mm.

The two methods' reliability test was performed using the intra-class correlation coefficient, and the

findings indicated good or excellent reliability. Bland-Altman plots (Fig. 4) for the measurements proved the findings mentioned above as the size of error was within the acceptable range, and nearly almost all the points lie within the limit of agreement and fairly close to the mean difference line, and this was confirmed by the results of the linear regression test where there were no significant differences (no proportional bias).



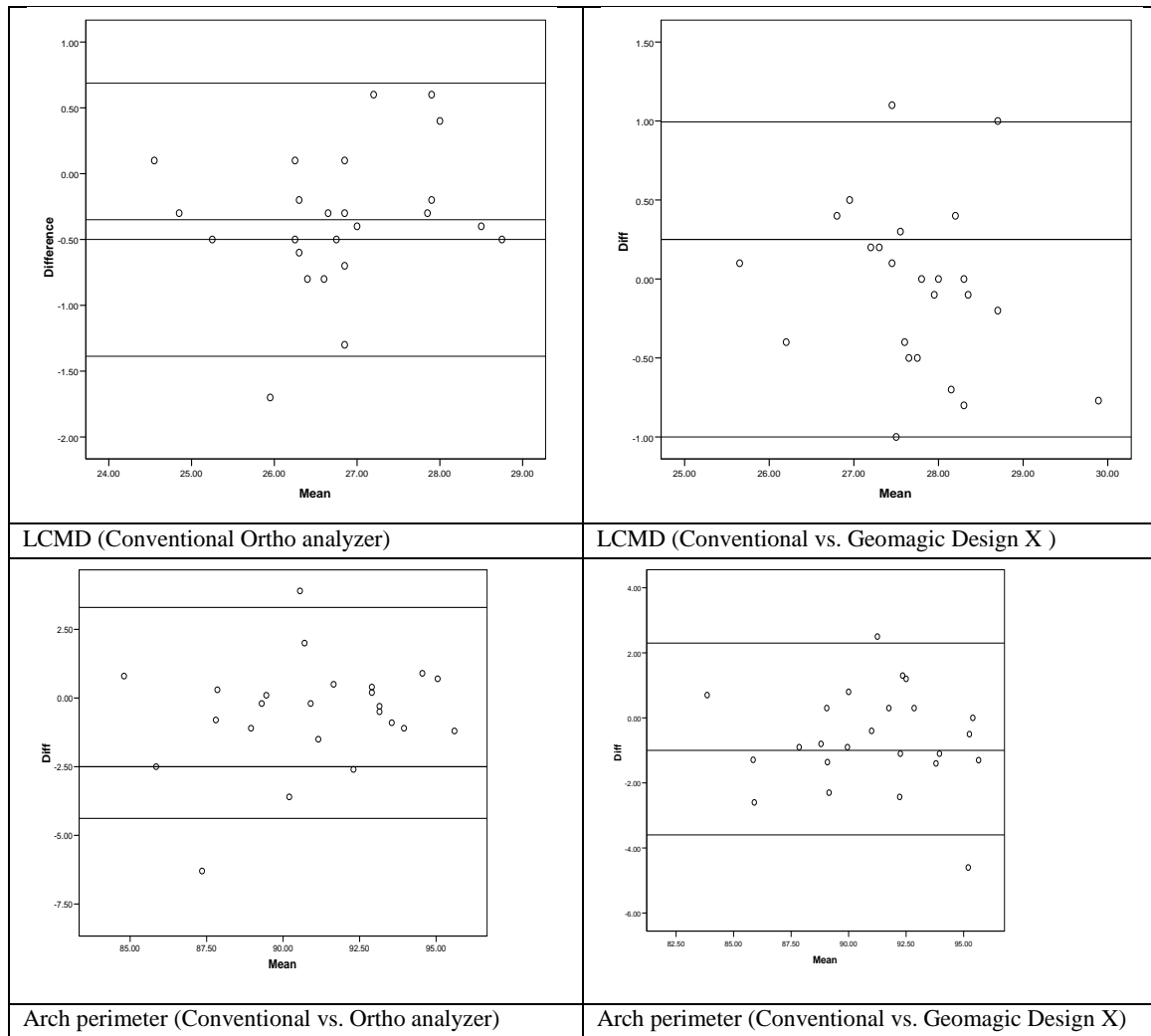


Fig. 4 Bland-Altman plots for the variables in the maxillary dental arch

Table 2 demonstrated the descriptive statistics of the maxillary and mandibular dental arch segments and perimeters measured using dental vernier directly on stone models and Geomagic Design X software for the

scanned models. Generally, all the mean values of the right and left distances were higher in the digital method.

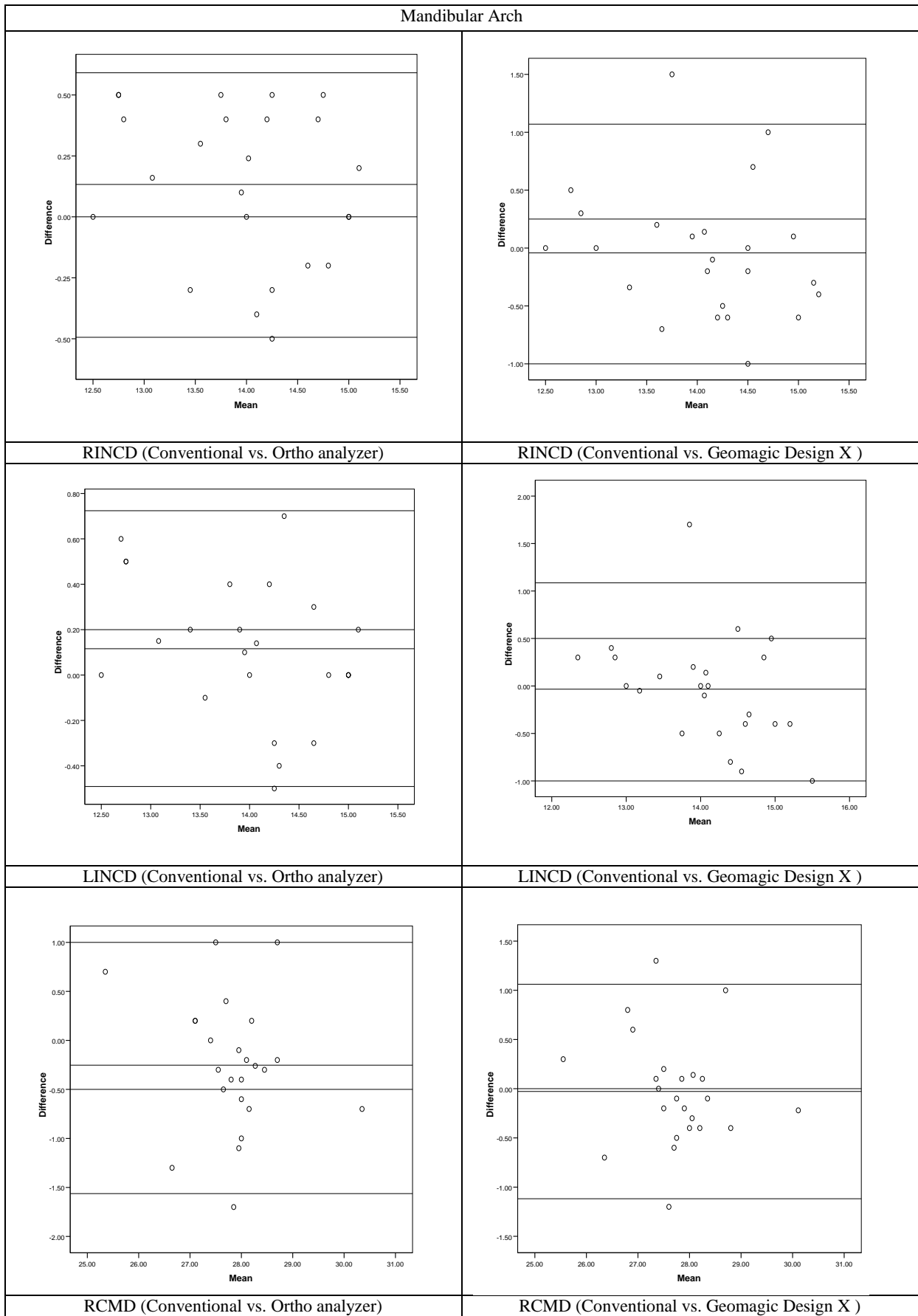
Table 2 Descriptive statistics, method difference, reliability, and linear regression test between the vernier and Geomagic Design X method

Arch	Measurements	Descriptive statistics				Method difference			Reliability	Regression			
		Vernier		Geomagic Design X		Mean difference	t-test	p-value		ICC	B	SE.	t-test
		Mean	SD.	Mean	SD.								
Maxillary	RINCD	18.758	0.904	18.833	1.063	-0.075	-0.760	0.455	0.881	-0.171	0.101	-1.697	0.104
	LINCD	18.746	0.891	18.900	1.086	-0.154	-1.393	0.177	0.851	-0.211	0.112	-1.878	0.074
	RCMD	26.608	1.113	26.835	1.066	-0.227	-2.795	0.010	0.933	0.045	0.079	0.571	0.574
	LCMD	26.600	1.129	26.793	1.010	-0.193	-1.950	0.064	0.897	0.117	0.096	1.221	0.235
	Arch perimeter	90.713	3.239	91.362	3.339	-0.649	-2.114	0.046	0.895	-0.032	0.100	-0.320	0.752
Mandibular	RINCD	14.042	0.750	14.083	0.868	-0.042	-0.360	0.722	0.756	-0.165	0.155	-1.063	0.299
	LINCD	14.058	0.753	14.092	0.963	-0.034	-0.289	0.775	0.782	-0.271	0.138	-1.966	0.062
	RCMD	27.727	0.880	27.755	0.958	-0.028	-0.250	0.805	0.817	-0.093	0.134	-0.698	0.492
	LCMD	27.700	0.845	27.749	0.950	-0.049	-0.449	0.658	0.825	-0.128	0.129	-0.988	0.334
	Arch perimeter	83.526	2.549	83.679	3.029	-0.153	-0.418	0.680	0.800	-0.190	0.138	-1.379	0.182

Systematic bias was determined by paired sample t-test. Principally, only the right canine-molar distance showed a significant difference, although the mean did not exceed 0.227 mm. The dental arch perimeter was significantly higher in the Geomagic Design X group, with a mean difference of 0.649 mm.

The reliability test of the two methods was

performed using the intra-class correlation coefficient, and the findings indicated good or excellent reliability. Bland-Altman plots (Fig. 5) for the measurements proved these findings just like in 3 shapes, and this was confirmed by the results of the linear regression test where there were no significant differences (no proportional bias).



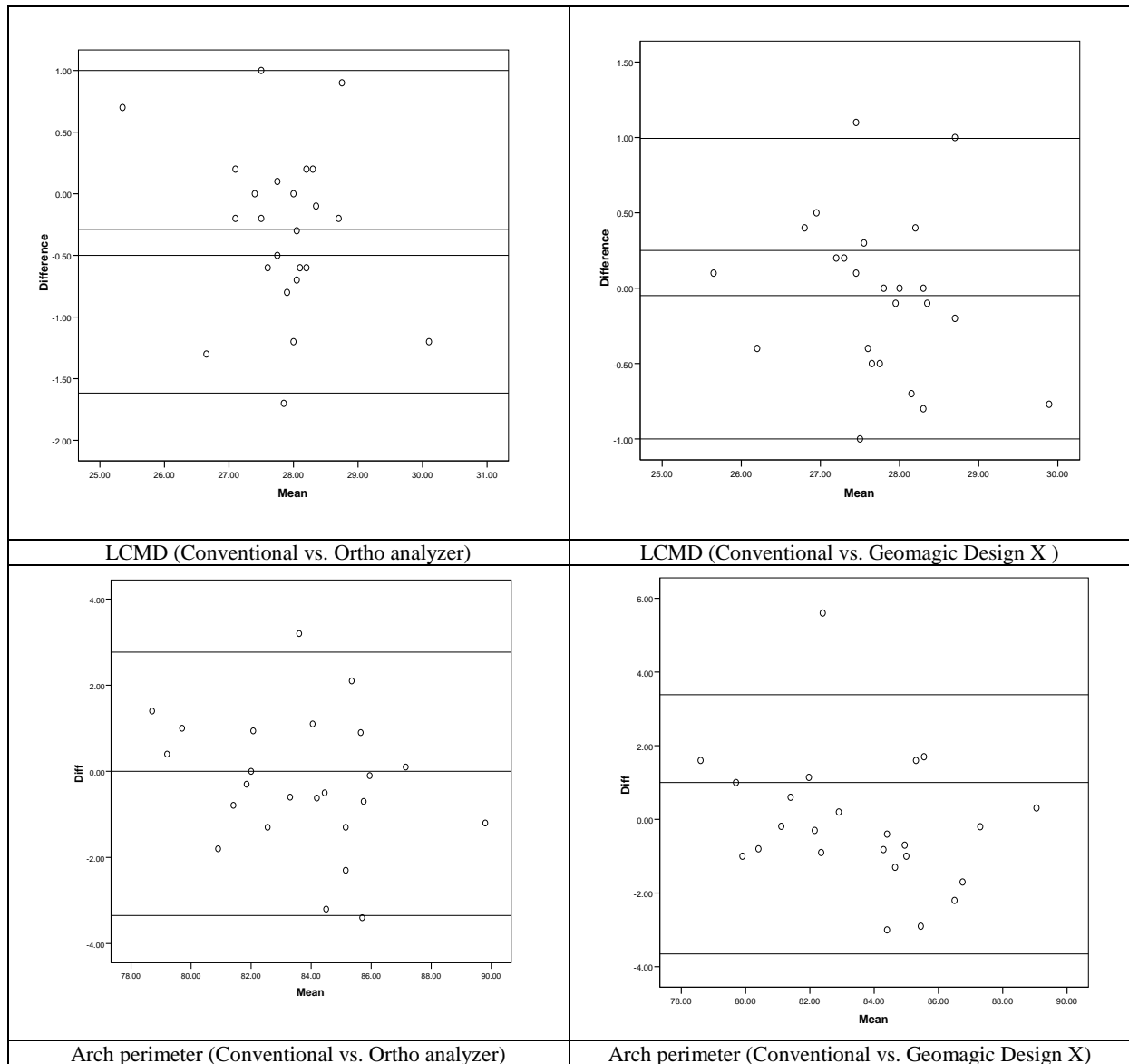


Fig. 5 Bland-Altman plots for the variables in the mandibular dental arch

Table 3 demonstrated the descriptive statistics of the maxillary and mandibular dental arch segments and perimeters measured by 3Shape and Geomagic Design X software on the scanned models. Generally, the mean

values of the right and left central incisor-canine distances were higher in the Geomagic Design X group and just the reverse for the canine-molar distances.

Table 3 Descriptive statistics, method difference, and reliability test between the 3Shape and Geomagic Design X methods

Arch	Measurements	Descriptive statistics				Method difference			Reliability
		3Shape		Geomagic Design X		Mean difference	t-test	p-value	ICC
		Mean	SD.	Mean	SD.				
Maxillary	RINCD	18.675	0.917	18.833	1.063	-0.158	-1.092	0.286	0.754
	LINCD	18.692	0.889	18.900	1.086	-0.208	-1.197	0.243	0.751
	RCMD	26.938	1.020	26.835	1.066	0.102	0.887	0.384	0.854
	LCMD	26.950	1.027	26.793	1.010	0.157	1.381	0.181	0.851
	Arch perimeter	91.254	2.863	91.362	3.339	-0.108	-0.239	0.814	0.750
Mandibular	RINCD	13.908	0.828	14.083	0.868	-0.175	-1.946	0.064	0.865
	LINCD	13.900	0.863	14.092	0.963	-0.192	-1.661	0.110	0.883
	RCMD	27.979	1.002	27.755	0.958	0.224	3.233	0.004	0.940
	LCMD	27.988	0.990	27.749	0.950	0.239	2.716	0.012	0.901
	Arch perimeter	83.817	2.930	83.679	3.029	0.138	0.611	0.547	0.931

Systematic bias was determined by paired sample t-test and revealed that only the right and the left canine-

molar distances in the mandibular arch showed significant differences, although the mean difference

was not exceeding 0.239 mm.

The reliability test of the two methods was performed using an intra-class correlation coefficient, and the findings indicated good or excellent reliability.

#### 4. Discussion

Digital models were considered suitable substitutes for stone models [20]; hence plaster and digital study models have been an important diagnostic tool to illustrate a suitable treatment plan [21]. The accuracy of digital methods in comparison with the manual caliper on plaster models regarding different arch measurements has been assessed in different studies.

This study was conducted for ascertaining whether or not digital models present a clinically useful and valid substitute to the plaster models and to find whether the measurements undertaken on the digital models using the Ortho Analyzer and the Geomagic design X are as statistically reliable as those taken from study models using the conventionally digital calipers with regards to dental arch perimeters.

Dental arch perimeters were determined as a sum of 4 linear distances; from the central incisor contact point to canine cusp tip (INCD) and from the latter to the distobuccal cusp of permanent first molar (CMD) on both sides.

The measurements were carried out on models of children during the mixed dentition stage (for the first time) by a single operator who had about 18 years of experience with dental model analyses to attain standardization and avoid errors that could happen between operators. Furthermore, undertaking 6 pairs of models each day also helped control operator stress and minimize systematic errors.

In orthodontics, Geomagic design X software is used for the second time after Al-Khannaq [22], while Ortho Analyzer software has been used in many kinds of research. From the present study results, it is obvious statistically that most of the parameters measured by digital models showed higher mean values than the vernier, particularly the CMD measured by the Ortho Analyzer program and INCD and CMD measured by the Geomagic design X program. These larger mean values obtained by the digital methods were also recorded by many other investigators, which possibly related to systematic overestimate of arch length done by the measurement tool [5, 7, 12-16], the process of data points' scanning and recording from plaster model, the algorithms of display and measurements of the proprietary software of the manufacturer, and the familiarity of the examiners with computer-based model measurements [20].

Although the mean difference did not exceed 0.542 mm. with the Ortho Analyzer and 0.649 mm. with the Geomagic design X, this difference was clinically acceptable and considered within the range of operator errors. The reliability between the vernier and both

software was good or excellent, confirmed by the Bland-Altman plots because the points were within the limit of agreement. Additionally, there is no greater number of points above and below the mean difference.

Systematic and random biases (errors) indicated a non-significant difference in most of the distances measured, indicating that these software and digital models are valid compared to the stone model and conventional measurement method. This result is under the findings of Bukhari et al. [23], who found a non-significant difference between plaster and digital models in assessing arch perimeter using conventional (vernier) and digital (Ortho Analyzer software) methods.

The minute difference in readings may be attributed to the variability in identifying landmarks as proposed by Houston [24]. They have stated that a very important source of random errors is the difficulty to identify the landmarks, that is to say, the ability of software in magnifying the scanned models on the screen to identify the landmarks is better moreover, the movement of the hands during the procedure of measurements and the weight of the models may have an impact on the precision of the conventional measurements.

On the other hand, some measurements recorded were higher with the conventional method than the digital ones like INCD, which had higher mean values than the Ortho Analyzer program with a statistically non-significant difference. This variation in measurements between the digital and the plaster models could be attributed to the fact that, in some cases, the vernier may overestimate or underestimate the readings as the operator uses one hand for handling the model and the other for measuring the distance. It might also be related to the inherent differences between both approaches because digital measurements show a 3D view, allowing better reference point locations. It includes digital tools for measuring distances along the chosen planes [1, 6, 8, and 25].

Generally, when testing the reliability of the two digitalized methods with the conventional vernier method by applying intra-class correlation coefficient, the findings indicated a good to excellent reliability. However, some differences were recorded between readings, but overall, these differences were not clinically significant, and this agrees with the findings of Quimby et al. [20].

The majority of the researchers have concluded that the digital models are acceptable clinically in the initial diagnoses and treatment planning despite some differences with statistical significance in variables between digital and analog formats. Considering all findings from the results obtained, one can infer that the differences are clinically acceptable, reproducibility is high, and there is consistent scientific evidence for supporting the validity of the measurements from

digital dental arch models compared to measurements directly obtained from them.

## 5. Conclusion

From the present study, the 3D scanned plaster model analysis appears to be an efficient and reliable alternative to the traditional model analysis method with a digital caliper on plaster models. Also, this study revealed that the reliability of digital models compared to plaster models is adequate for diagnostic applications for orthodontic purposes.

According to the findings of the present study, when comparing the manual measurements on the plaster models with the digital measurements by applying for software programs on scanned models, a good to excellent reliability between these methods have gained with the advantage of digital models presents a high validity degree and any variances in the measurements in the present research between the approaches will possibly be acceptable clinically.

Further scientific research needs to assess the reliability and validity of the Geomagic Design X software program in various dental arch measurements and to compare the results with other software programs applications because few studies were applied for such programs in orthodontic diagnosis. Furthermore a comparison in the time needed to perform the measurements on digital models with the time needed to measure on plaster models with the use of conventional calipers. The main limitation of the present study is the small sample size, so further studies with a larger sample are needed.

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