## Medicine



# Difference between manual and digital measurements of dental arches of orthodontic patients

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#### Abstract

The objective of this study was to compare the differences between the measurements performed manually to those obtained using a digital model scanner of patients with orthodontic treatment.

A cross-sectional study was performed in a sample of 30 study models from patients with permanent dentition who attended a university clinic between January 2010 and December 2015. For the digital measurement, a Maestro 3D Ortho Studio scanner (Italy) was used and Mitutoyo electronic Vernier calipers (Kawasaki, Japan) were used for manual measurement. The outcome variables were the measurements for maxillary intercanine width, mandibular intercanine width, maxillary intermolar width, mandibular intercanine width, overjet, overbite, maxillary arch perimeter, mandibular arch perimeter, and palate height. The independent variables, besides age and sex, were a series of arc characteristics. The Student *t* test, paired Student *t* test, and Pearson correlation in SPSS version 19 were used for the analysis.

Of the models, 60% were from women. Two of nine measurements for pre-treatment and 6 of 9 measurements for post-treatment showed a difference. The variables that were different between the manual and digital measurements in the pre-treatment were maxillary intermolar width and palate height (P < .05). Post-treatment, differences were found in mandibular intercanine width, palate height, overjet, overbite, and maxillary and mandibular arch perimeter (P < .05).

The models measured manually and digitally showed certain similarities for both vertical and transverse measurements. There are many advantages offered to the orthodontist, such as easy storage; savings in time and space; facilitating the reproducibility of information; and conferring the security of not deteriorating over time. Its main disadvantage is the cost.

Abbreviation: CBCT = cone beam computed tomography.

Keywords: digital measurement, manual measurement, study models

#### 1. Introduction

The orthodontic diagnosis, as in any other dental specialty, is a main element in establishing and specifying the goals of correct

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Received: 17 November 2017 / Accepted: 8 May 2018 http://dx.doi.org/10.1097/MD.000000000010887 treatment.<sup>[1]</sup> Knowing, recognizing, and defining the relationships between skeletal, dental, facial, and functional problems play a fundamental role in specifying individual characteristics and in ordering priority in the treatment plan.<sup>[2]</sup>

Plaster models are used to improve the orthodontic diagnosis. Specifically, they are used to visualize the morphology and position of the teeth in their respective dental arches, as well as to provide a 3-dimensional model of the patient's occlusion. Traditional plaster models have a long history as diagnostic materials, but they present some drawbacks such as space problems and/or the risk of rupture as a result of the nature of the materials with which they are made.<sup>[3,4]</sup> Digitization of the models offers the orthodontist an alternative to study them, because it allows evaluation of the sagittal, vertical, and horizontal planes with an almost real approximation.<sup>[5,6]</sup> There are currently 3 methods of reproducing digital orthodontic study models: laser scanning of plaster models or impressions; cone beam computed tomography (CBCT) of orthodontic impressions or plaster models; and intraoral laser scanning of dental arches or scans of plaster models in the office.<sup>[7]</sup>

Comparative studies on the agreement between digital and manual measurements are useful to support or refute the use of virtual models in clinical practice and research.<sup>[8]</sup> Thus, in Germany, Radeke et al<sup>[9]</sup> performed a study on 55 pairs of plaster models, which were derived from patients who had not

undergone orthodontic treatment, to compare manual and digital measurements. The models were digitized and measured using OnyxCeph3 software (Image Instruments Chemnitz, Germany) and conventional Vernier calipers. The recorded measure of each tooth was the mesio-distal width from the right upper first molar to the upper left first molar in the maxilla and mandible. They identified that there were no statistically significant differences when comparing the measurements made with the software and with the calibrator. In another study conducted in a Brazilian sample, Rosseto et al<sup>[10]</sup> compared measurements manually performed with an electronic Vernier caliper and digitally with the software RadioCef 2000 (Radiomemory Co, Belo Horizonte, MG, Brazil). In 130 pairs of plaster models obtained in the pretreatment and post-treatment phases, the intercanine and intermolar widths were measured in the maxilla and mandible. No statistically significant differences were found between the 2 methods. Watanabe-Kan et al<sup>[11]</sup> compared the reliability and validity of the measurements in digital models compared with the plaster models. They obtained 15 pairs of plaster models from Brazilian patients with permanent dentition before of the orthodontic treatment, which were digitized to be measured using the Cécile3 program version 2.554.2 beta. The plaster models were measured using a digital Vernier caliper (Mitutoyo, model 500-144B, Tokio, Japan). The measures considered were the mesiodistal width of the teeth present, intercanine width, interprelobling width, intermolar width, overjet, and maxillary and mandible overbite. No statistically significant differences were found.

Although some numerical discrepancies have been found, there were no significant differences between the measurement methods used. Therefore, it has been suggested that the use of plaster models is suitable for measurements. However, digital models have demonstrated a high degree of accuracy, and much of the measurement technique error is likely to reside in the identification of measurement reference points rather than an error in the measurement device or software used.<sup>[12]</sup>

In Mexico, there are no studies investigating this issue, so the objective of this study was to compare the differences between measurements made with a scanner in digital models and hand measurements made on traditional plaster models before and after orthodontic treatment.

#### 2. Material and methods

#### 2.1. Study design and sample selection

A cross-sectional study was performed. The method of sample selection was non-probabilistic. We included study models of 30 patients with permanent dentition who attended the Advanced Studies and Research Centre in Dentistry, Dr. Keisaburo Miyata Faculty of Dentistry at the Autonomous University State of Mexico, between January 2010 and December 2015. All patients were treated using the edgewise standard technique.

The inclusion criteria for the plaster models were as follows: patients older than 13 years old; both sexes; permanent dentition; no loss of apparent dental substance resulting from attrition or decay; and no missing teeth from the first molar to the first molar. The exclusion criteria were as follows: plaster models from patients who previously received orthodontic or orthopedic treatment; with previous surgical treatment; with changes in craniofacial growth; and with dental alterations of the size and number of the teeth.

#### 2.2. Variables and data collection

For the measurement of plaster models, both pre-treatment and post-treatment, a Maestro3D Ortho Studio scanner (AGE Solutions, Pisa, Italy) was used in the digital measurement. On the contrary, measurements were obtained on the plaster models using a Mitutoyo electronic caliper (Mitutoyo, Kawasaki, Japan) equipped with a Vernier scale that was accurate to 0.01 mm. Measurements on the models using both methods were as follows: maxillary intercanine width; mandibular intercanine width; maxillary intermolar width; mandibular intermolar width; overjet; overbite; maxillary arch perimeter; mandibular arch perimeter; and palate height. The dependent variables were the crude measurements of each of the previous indicators. The differences in the manual measurement minus the digital measurement were obtained, which were contrasted with the independent variables.

The independent variables included were as follows: age (whole years completed), sex (0=male, 1=female); molar class (0=class I, 1=class II, 2=class II div 1, 3=class II div 2, 4=class III); arch shape (0=oval, 1=square, 2=triangular); and extraction and nonextraction treatment (0=extractions, 1=nonextractions).

#### 2.3. Statistical analysis

The SPSS version 19 (SPSS Inc., Chicago) statistical package was used to analyze the data, where a descriptive analysis was performed using the central tendency and dispersion measures for the quantitative variables. Categorical variables were reported as frequencies and percentages.

The bivariate analysis was performed using the following tests: *t*-test for independent samples, *t* test for dependent samples, and Pearson correlation. The level of statistical significance was set at P < .05.

Error studies were performed on the various methods based on the repeated measures of 1 observer, previously trained and standardized. The error was less than 0.5 mm and was found to be not statistically significant (P > .05).

#### 2.4. Ethical considerations

The present investigation complied with the specifications of the General Health Law in Research in Mexico. This study does not carry a risk because it does not compromise the physical, moral, or emotional integrity of the people involved. The protocol was reviewed and approved by the ethics committee of the Advanced Studies and Research Centre in Dentistry, Dr. Keisaburo Miyata Faculty of Dentistry at the Autonomous University State of Mexico. Because we worked with plaster models, no informed consent was required. No humans were involved in the study.

#### 3. Results

#### 3.1. Descriptive results

The sample consisted of plaster models of pre- and postorthodontic treatment from 30 patients with permanent dentition. Table 1 summarizes the results of the univariate analysis, in which we observed that 60% were female; 70% had undergone extraction treatment. In addition, 36.7% of the initial right molar class was class II and 43.3% of the left molar class was class I. At the beginning of the treatment, the most common arch shape was oval, both in maxillary (with 63.3%) and mandible (with

 Table 1

 Descriptive analysis for the study variables.

Variable	Frequency	Percentage
Pre-treatment		
Sex		
Male	12	40.0
Female	18	60.0
Extraction and nonextraction treatment		
Extraction	21	70.0
Nonextraction	9	30.0
Initial right molar class		
Class I	9	30.0
Class II	11	36.7
Class II division 1	4	13.3
Class II division 2	3	10.0
Class III	3	10.0
Initial left molar class		
Class I	13	43.3
Class II	7	23.3
Class II division 1	4	13.3
Class II division 2	3	10.0
Class III	3	10.0
Shape of the initial maxillary arch		
Oval	19	63.3
Square	5	16.7
Triangular	6	20.0
Shape of the initial mandibular arch		
Oval	28	93.3
Square	1	3.3
Triangular	1	3.3
Post-treatment		
Final right molar class		
Class I	29	96.7
Class II	1	3.3
Final left molar class		
Class I	28	93.3
Class II	1	3.3
Class III	1	3.3
Final maxillary arch shape		
Oval	29	96.7
Square	1	3.3
Triangular	0	0
Final mandibular arch shape		
Oval	29	96.7
Square	1	3.3
Triangular	0	0

93.3%), while at the end of the treatment, the oval shape predominated in both the maxillary and mandibular arches. The final molar class was class I.

#### 3.2. Results of manual and digital measurements

Manual and digital measurements were compared in pretreatment and in orthodontic post-treatment, for which a paired Student *t* test was used. The results of manual compared with digital measurements from the pre-treatment models are summarized in Table 2. Statistically significant differences were observed in the maxillary intermolar width (P=.030) and palate height (P=.002). All measurements showed a strong correlation.

Results from the post-treatment models are summarized in Table 3. Statistically significant differences were observed for the mandibular intercanine width (P=.001), palate height (P=.001), overjet (P<.006), overbite (P=.005), perimeter of the maxillary

#### Table 2

Results of manual compared with digital measurements in pretreatment models.

Variable	Manual	Digital	P	$\mathbf{Correlation}^{\dagger}$
Maxillary intercanine width	35.73±3.17	35.32 ± 2.94	.238	r=0.823; P<.001
Mandibular intercanine width	28.19±2.91	28.01 ± 2.72	.457	r=0.892; P<.001
Maxillary intermolar width	$52.05 \pm 3.26$	52.39±3.37	.030	r=0.971; P<.001
Mandibular intermolar width	$45.99 \pm 3.12$	45.72±2.64	.462	r=0.763; P<.001
Palate height	$20.05 \pm 2.70$	19.13±3.08	.002	r=0.878; P<.001
Overjet	3.08±2.16	2.97 ± 2.02	.719	r=0.741; P<.001
Overbite	2.05±1.71	2.74 ± 2.36	.061	r=0.583; P=.001
Maxillary arch perimeter	72.37 ± 4.94	72.59±6.18	.786	r=0.700; P<.001
Mandibular arch	$64.45 \pm 4.70$	$63.16 \pm 5.34$	.131	r=0.600; P<.001

Paired t test.

<sup>†</sup> Pearson correlation of manual versus digital measurements.

arch (P = .012), and in the perimeter of the mandibular arch (P = .028). The overbite showed no correlation (p > .05).

### 3.3. Bivariate results of the difference of the measurements (manuals –digital)

Differences between the manual and digital measurements (manual – digital measurements), as dependent variables, were tested with the Student *t* test for independent samples (results not showed). Pretreatment only shows statistically significant differences by sex when comparing the mandibular intercanine width (P < .05). On the contrary, post-treatment results showed significant differences between the sexes in the maxillary intercanine width and mandibular arch perimeter (P < .05 for each). The overjet and perimeter of the maxillary arch were different according to the variable treatment with/without extractions (results no showed).

#### 4. Discussion

In this study, several variables showed significant differences between manual and digital measurements. This may be a result of the intrinsic differences between the 2 methods, because the digital measurement shows a 3-dimensional view that allows better location of the reference points, and it contains digital tools to measure diameters and distances along selected planes. Differences were found between the 2 measurements, in the overbite and the overjet in the post-treatment. This is consistent with Stevens et al<sup>[13]</sup> and Santoro et al,<sup>[6]</sup> who suggest that observing a smaller tooth size when measuring them digitally compared with measuring them directly in the plaster model results in an overbite effect of millimeters. Another factor that could be attributed to this difference is a variation in the vertical plane used for the measurement in the 2 methods, because this plane is selected randomly for manual measurements.

In contrast to the findings of this study, where only a few significant differences were found in the measurements, Zilberman et al<sup>[14]</sup> reported that measurements obtained directly from plaster models using electronic Vernier calipers were more accurate and reproducible than those obtained using digital measurement tools. However, a systematic review of manual and digital measurements<sup>[4]</sup> describes few differences between these methods. Generally, these differences were not clinically

Table 3

Results of manual compared with digital measurements in post-treatment models.

Variable	Manual	Digital	P <sup>*</sup>	<b>Correlation</b> <sup>†</sup>
Maxillary intercanine width	$36.92 \pm 3.27$	36.91±3.13	.952	r=0.983; P<.001
Mandibular intercanine width	28.77±1.79	29.22±1.87	.001	r=0.930; P<.001
Maxillary intermolar width	52.10±2.85	$52.43 \pm 2.75$	.056	r=0.948; P<.001
Mandibular intermolar width	44.72±3.42	44.93±3.28	.294	r=0.953; P<.001
Height of the palate	22.10 ± 2.97	$19.93 \pm 2.64$	.001	r=0.569; P=.001
Overjet	$2.38 \pm 0.48$	$2.14 \pm 0.63$	.006	r=0.707; P<.001
Overbite	$2.03 \pm 0.40$	$2.44 \pm 0.71$	.005	r=0.213; P=.258
Maxillary arch perimeter	$68.01 \pm 6.36$	$66.65 \pm 6.63$	.012	r=0.898; P<.001
Mandibular arch perimeter	$58.04 \pm 6.53$	$57.02 \pm 6.45$	.028	r=0.931; P<.001

\* Paired *t* test.

\* Pearson correlation of manual versus digital measurements.

significant, as evidenced by studies that demonstrate excellent agreement between treatment planning decisions that are based on digital and plaster models.<sup>[15,16]</sup> In this study, except for the overbite (in post-treatment), strong correlations were found between the measurements both pre-treatment and post-treatment. On the contrary, the pre-treatment only shows statistically significant differences by sex when comparing the mandibular intercanine width (P < .05); this could be due to the fact that in general all the dimensions of the dental arch are slightly higher in men than in women. However, it is reported that men have a greater variability of these values. In addition, it is established that there is a strong correlation between the intercanine width and the square and ovoid arch forms.

It has been suggested that digital study models offer advantages, including feasibility of storage, retrieval of information, ease of transfer if necessary, potentially equal or better diagnostic capabilities, and the benefit of sending virtual images for referral or instant consultation.<sup>[13]</sup>

Some of the advantages of plaster models are the high level of physical permanence over time and a relatively low cost of production. However, they also have disadvantages such as the risk of fracture, storage costs, time needed to recover them, the considerable risk that they may be damaged, and their use for consultation or review entails manipulation and transportation needs.<sup>[5,6]</sup> These disadvantages may become significant, so the use of digital models as substitutes for plaster models has been suggested, but the digital model method has not yet been well accepted.

One of the main advantages of plaster models is that they are more economical, so their use in developing countries, as Mexico or Latin America countries, would have to be studied in a costeffectiveness assessment. In addition, patient comfort should be investigated.

The use of digital measurements is a good alternative for the evaluation of pre- and post-treatment occlusion, providing an excellent tool for orthodontists because of their ease of storage in a computer, the savings in time and space, and facilitating the reproducibility of information with other disciplines; they will also be available for a long period of time without the risks of physical deterioration that may occur with plaster models. However, the main disadvantage is the cost.<sup>[10,17]</sup>

One of the limitations of this study is that digital models present several challenges compared with plaster models. Because the 3-dimensional computer image is displayed on a 2dimensional screen, it was a challenge to measure the overjet and overbite. This may depend on the approach and rotation, and the vertical or horizontal section function of the software is helpful with this. However, similar studies that analyze the models and compare the 2 methods using more measurements are required.

#### 5. Conclusion

The models measured manually and digitally showed certain similarities for both vertical and transverse measurements, because in most of the measurements, no significant difference was observed; 2 of 9 measurements for pre-treatment and 6 of 9 for post-treatment showed significant differences.

The use of digital models has been gaining acceptance in recent years, largely because they are a useful alternative in the evaluation of pre- and post-treatment. There are many advantages offered to the orthodontist, such as easy storage; savings in time and space; facilitating the reproducibility of information; and conferring the security of not deteriorating over time. Its main disadvantage is the cost.

#### Author contributions

S I Jiménez-Gayosso, E Lara-Carrillo, S López-González, and C E Medina-Solís contributed to conception, design, data acquisition, analysis, interpretation, and drafted the manuscript; R J Scougall-Vilchis, C T Hernández-Martínez, G E Colomé-Ruiz, M Escoffié-Ramirez contributed to data analysis and interpretation, drafted the manuscript, and critically revised it. All authors gave final approval and agree to be accountable for all aspects of the work. **Conceptualization:** Sandra Isabel Jiménez-Gayosso, Edith

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