Comparative study of dental arch width in plaster models, photocopies and digitized images

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Abstract: The aim of this study was to comparatively assess dental arch width, in the canine and molar regions, by means of direct measurements from plaster models, photocopies and digitized images of the models. The sample consisted of 130 pairs of plaster models, photocopies and digitized images of the models of white patients (n = 65), both genders, with Class I and Class II Division 1 malocclusions, treated by standard Edgewise mechanics and extraction of the four first premolars. Maxillary and mandibular intercanine and intermolar widths were measured by a calibrated examiner, prior to and after orthodontic treatment, using the three modes of reproduction of the dental arches. Dispersion of the data relative to pre- and posttreatment intra-arch linear measurements (mm) was represented as box plots. The three measuring methods were compared by one-way ANOVA for repeated measurements ($\alpha = 0.05$). Initial / final mean values varied as follows: 33.94 to 34.29 mm / 34.49 to 34.66 mm (maxillary intercanine width); 26.23 to 26.26 mm / 26.77 to 26.84 mm (mandibular intercanine width); 49.55 to 49.66 mm / 47.28 to 47.45 mm (maxillary intermolar width) and 43.28 to 43.41 mm / 40.29 to 40.46 mm (mandibular intermolar width). There were no statistically significant differences between mean dental arch widths estimated by the three studied methods, prior to and after orthodontic treatment. It may be concluded that photocopies and digitized images of the plaster models provided reliable reproductions of the dental arches for obtaining transversal intra-arch measurements.

Descriptors: Dental arch; Measures; Malocclusion; Orthodontics.

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Introduction

Stability is one of the major goals of orthodontic treatment. Nonetheless, it still remains a controversial issue, perhaps because it involves a multitude of intrinsic and extrinsic factors. Intercanine and intermolar widths are widely discussed, and their maintenance is considered an important factor in attaining stability after treatment.[1,2] From a clinical point of view, it is well-known that these measurements undergo changes in cases treated with extraction of the four first premolars.

Technological advances have provided faster measuring methods, which make it easier to obtain the above mentioned parameters.[3-5] Thus, the present study aimed at evaluating the reliability of intercanine and intermolar widths taken on plaster models (gold standard), photocopies and digitized images of the models of orthodontic patients treated with premolar extractions. The null hypothesis stated that there are no differences in performance between the studied measuring methods.

Material and Methods

This study is in agreement with Resolution 196/96 from the National Health Council/Health Department (Brazil).

Sample selection

The sample comprised 130 pairs of orthodontic plaster models obtained at the pretreatment and posttreatment phases. The selected subjects included 65 white patients (41 female and 24 male) with Angle Class I (n = 33) and Angle Class II Division 1 (n = 32) malocclusions, orthodontically treated by standard Edgewise (not preadjusted) technique, with extraction of the four first premolars. The patients began treatment at ages ranging from 10 to 18 years.

Dental arch width measurements

Maxillary and mandibular intercanine and intermolar widths were measured using as references the canine cusp tip and the molar mesiobuccal cusp tip, on the right and left sides. Reference points were identified and marked with ultrafine graphite (0.5 mm in diameter – Pentel Co. Ltd., Tokyo, Japan) on each orthodontic plaster model at the pre- and posttreatment phases. In cases of cusp tip flattening by wear, the reference point (estimated cusp tip) was marked as the central point in the middle of the wear facet, according to Bishara *et al.*[6] (1994), Freitas *et al.*[7] (1996) and McReynolds, Little[8] (1991), in previous studies. Measurements were made by a calibrated examiner directly on the plaster models and photocopies of the models using a digital caliper (Mitutoyo®, Digimatic, Kawasaki, Japan) accurate to 0.01 mm. All photocopies were acquired by means of a Xerox® X-C865 machine (Stanford, CT, USA) with the models in the most stable position.[9]

In addition, all models were digitized using a scanner (ScanJet 2200C®; Hewlett Packard Co., Greeley, CO, USA) at a resolution of 300 dpi. The digitized models were then stored as TIFF (Tagged Image File Format) images. Reference landmarks for measuring the intercanine and intermolar widths were identified and marked from a laptop display (Acer® 350; Acer Inc., Taipei, Taiwan). Maxillary and mandibular intercanine and intermolar widths were calculated using the RadioCef® 2000 software (Radiomemory Co., Belo Horizonte, MG, Brazil).

Method error

To estimate reproducibility, measurements from the three modes of reproduction of the dental arches were made twice. Following a calibration session, 20 pairs of plaster models were randomly selected, reproduced and assessed by the examiner. A two-week interval was allowed to elapse between the first and the second assessment. For the analyses of systematic and casual errors, Student's-*t* test and Dahlberg's formula were used, respectively. Systematic errors were not statistically significant ($p > 0.05$). The casual errors varied from 0.12 mm to 0.35 mm, according to the region measured (canine or molar) and mode of reproduction of the dental arches. Casual errors in this range may be considered clinically acceptable.

Statistical analysis

The descriptive statistics of the intercanine and intermolar width measurements (mm) obtained from the three modes of reproduction of the dental arches, for the pretreatment (initial) and posttreatment (final) phases, were presented as box plots. The box stretches from the lower hinge (defined as the 25th percentile) to the upper hinge (75th percentile) and, therefore, contains the middle half of the values in the distribution. The median is shown as a line across the box.

Differences in the performance of the methods were evaluated by one-way ANOVA for repeated measurements, prior to and after treatment ($\alpha = 0.05$).

Results

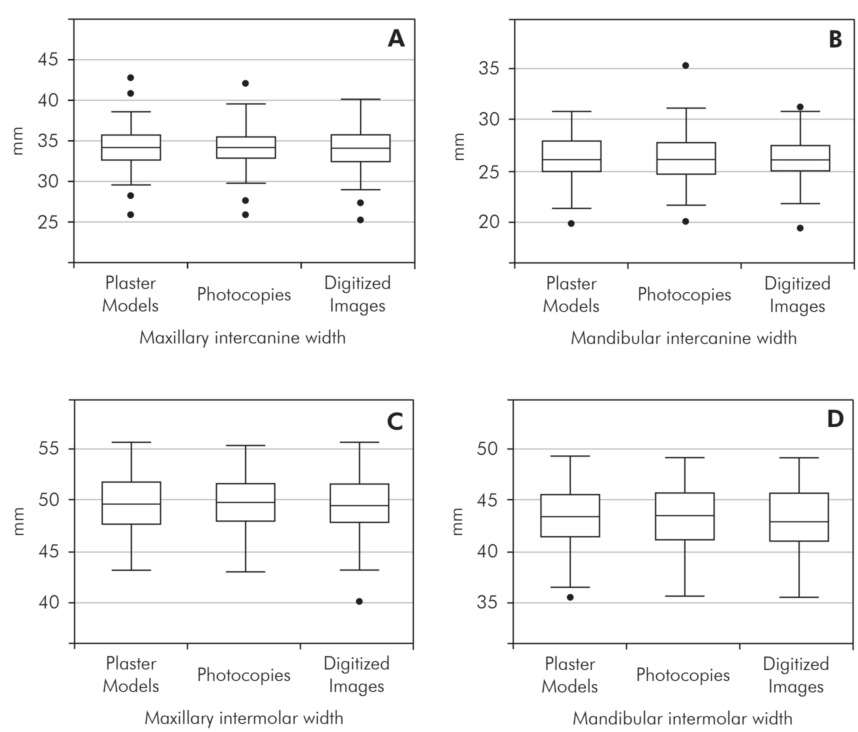
Distribution patterns of the initial (pretreatment) measurements are represented in Graph 1. The measurements taken on the plaster models, photocopies and digitized images evidenced a similar distribution for both intercanine and intermolar widths. As shown in Graph 2, the distribution patterns relative to the three studied modes of reproduction of the dental arches remained apparently analogous after treatment. Based on the five-number summaries of the graphs and mean values, it may be suggested that maxillary and mandibular intermolar widths presented a slight decrease in the posttreatment assessments (Graphs 1 and 2, Tables 1 and 2). Median values were very close to the respective mean values, indicating symmetry of the data distribution.

Despite the numerical discrepancies, no significant differences were found between the measuring methods (Tables 1 and 2).

Discussion

Orthodontic plaster models have long been extensively used for diagnosis and in treatment outcomes assessment. While communication technology was advancing, some modes of reproducing the traditional plaster models were developed.[10] Such diagnostic tools could not only address the universal problem of plaster model storage in an orthodontic office, but also shorten the time necessary to perform measurements and analysis of the dental arches.[11] In this way, plaster models would be used just once because after acquiring two- or three-dimensional images they could be given to the patients.

Despite some numerical discrepancies, there were no significant differences between the studied measuring methods (Tables 1 and 2). Hence, it may be suggested that orthodontic plaster models, photocopies and digitized images of the models are



Graph 1 - Box plot diagrams illustrating the distribution pattern for the initial measurements (mm) of maxillary and mandibular intercanine and intermolar widths taken on plaster models, photocopies and digitized images.

Graph 2 - Box plots representing the distribution pattern for the final measurements (mm) of maxillary and mandibular intercanine and intermolar widths taken on plaster models, photocopies and digitized images.

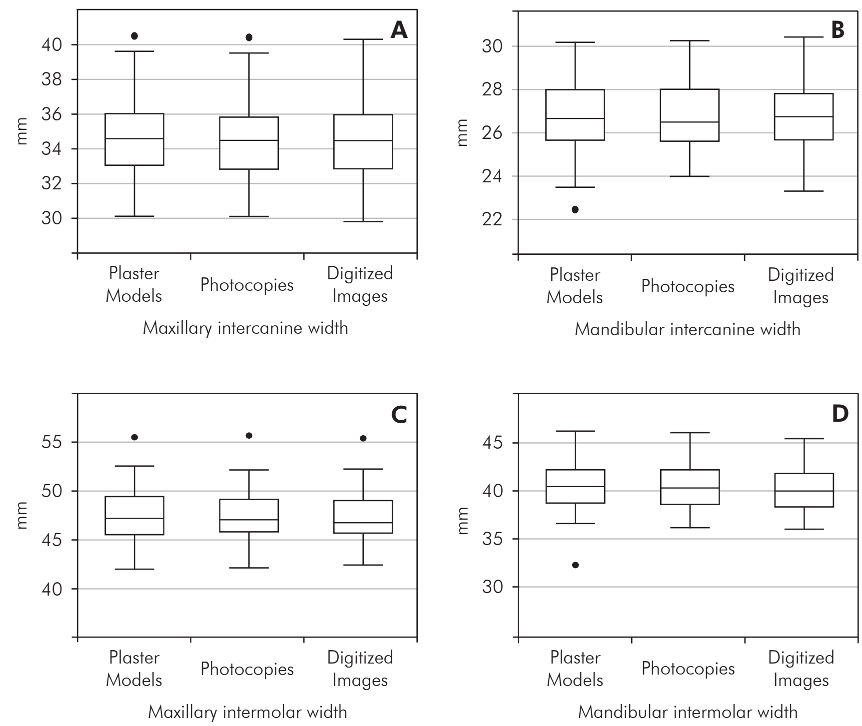


Table 1 - Comparisons between measuring methods of arch width in the pretreatment phase (initial measurements).

Initial Measurements (mm)								
Region	Plaster Models		Photocopies		Digitized Images		Comparison	
	Mean	(s.d.)*	Mean	(s.d.)*	Mean	(s.d.)*	F	p value**
Maxillary canine	34.29	(2.81)	33.97	(2.66)	33.94	(2.88)	0.31	0.7314
Maxillary molar	49.60	(3.18)	49.66	(3.16)	49.55	(3.22)	0.02	0.9809
Mandibular canine	26.23	(2.35)	26.25	(2.48)	26.26	(2.31)	0.00	0.9974
Mandibular molar	43.41	(3.04)	43.40	(2.97)	43.28	(3.00)	0.04	0.9581

*s.d.: standard deviation. **p > 0.05.

Table 2 - Comparisons between measuring methods of arch width in the posttreatment phase (final measurements).

Final Measurements (mm)								
Region	Plaster Models		Photocopies		Digitized Images		Comparison	
	Mean	(s.d.)*	Mean	(s.d.)*	Mean	(s.d.)*	F	p value**
Maxillary canine	34.66	(2.09)	34.53	(2.05)	34.49	(2.12)	0.12	0.8868
Maxillary molar	47.45	(2.63)	47.44	(2.57)	47.28	(2.49)	0.09	0.9168
Mandibular canine	26.77	(1.63)	26.83	(1.59)	26.84	(1.61)	0.04	0.9630
Mandibular molar	40.46	(2.58)	40.41	(2.35)	40.29	(2.36)	0.08	0.9213

*s.d.: standard deviation. **p > 0.05.

suitable reproductions for taking measurements of the anterior and posterior dental arch width. The results of the present study were generally consistent with those reported by Champagne[12] (1992). In fact, Simplício *et al.*[13] (1995) found more evident distortions in photocopies of the mandibular models. This finding may be related to the curve of Spee, which is reflected to a greater extent in the canine and premolar regions on photocopies.

Overall satisfactory reliability of transversal measurements made on digitized images of plaster models was demonstrated in several investigations.[3,5,14-17] Moreover, measuring patient's dentition and calculating the Bolton ratio with scanned models (emodels) appeared to be just as accurate and faster than using digital calipers with plaster models.[11] Vasconcelos *et al.*[4] (2006) reported that the Radiocef® 2.0 software, used in this study, provided good reliability for taking measurements from digitized tracings. Therefore, it would be reasonable to assume that digitized images of orthodontic plaster models may be useful as adjuncts for measuring occlusal parameters in clinical practice. Nevertheless, taking linear interarch measurements like overjet on scanned plaster models is not recommended as a substitute method for manual assessment.[10] Hildebrand *et al.*[10] (2008) stated that the digital mounting of the scanned plaster models allows the teeth to overlap, creating improper articulation because two objects cannot occupy the same space.

Concerning the behavior of the measurements estimated by the three methods, it was found that the intermolar width was decreased after treatment in patients with Class I and Class II Division 1 malocclusions, both in the maxillary and mandibular arch (Graphs 1 and 2, Tables 1 and 2). These results are in agreement with those reported by other studies.[6,7] Presumably, the reduction in the posterior arch width was due to the loss of anchorage. Some authors[2] mentioned that the increase of this measurement may be an important factor related to post-treatment relapse. On the other hand, the decrease in posterior arch width seems to have little clinical relevance. The increase in transversal dimensions, i.e. intercanine and intermolar widths, produced during orthodontic treatment has been associated to long-term reduced stability due to a trend towards anterior crowding.[2,18] Conversely, decreased intercanine and intermolar widths should not be considered risk factors for the greater probability of incisors crowding relapse in the mandibular arch.[7]

From a critical perspective of the Brazilian legal guidelines, it is recognized that the mandatory filing of orthodontic documentation for around 20 years increases the demands for physical space, particularly to keep the plaster models. Photocopies would not constitute the method of choice for proper replacement of plaster models, since they depict two-dimensional static images and do not allow the assessment of maxillo-mandibular relationships. Scanning orthodontic plaster models may provide three-dimensional images and, additionally, offers the possibility of computed-manipulation to improve clinical diagnosis.[11,14] Enhancement features of digitized images, as opposed to the limitations of photocopies, would highlight the former reproduction method as an adequate substitute for the traditional orthodontic plaster models. Although there are some drawbacks that still must be overcome, scanned models carry the potential for notably simplifying and improving orthodontic diagnosis.

Orthodontic files could be much smaller if digitized images of plaster models were used. The reproduction method also yields on-line exchange of diagnostic information. However, some care must be taken during the digitization process. An appropriate scanner is needed, a minimum resolution of 300 dpi must be selected and the acquired pictures should be stored as TIFF images. Nowadays, there are commercially available systems specially developed for scanning dental casts, which acquire dynamic three-dimensional images. Based on an overview of the current knowledge, with the increasing applications of cone-beam computed-tomography in Orthodontics, it would perhaps be feasible to take measurements directly from tomographic images of the dental arches. Possibly, in the near future, obtaining alginate impressions will no longer be necessary.

Conclusions

1. Orthodontic plaster models, photocopies and digitized images demonstrated similar performance for measuring maxillary and mandibular intercanine and intermolar widths.
2. Considering the demand for physical space in a dental office, it may be suggested that a digitized image is a suitable alternative to a traditional plaster model for obtaining transversal intra-arch measurements.

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