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Agreement in the determination of preformed wire shape templates on plaster models and customized digital arch form diagrams on digital models

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Introduction: The aim of this study was to verify the accuracy of preformed wire shape templates on plaster models and those of customized digital arch form diagrams on digital models. **Methods:** Twenty pairs of dental plaster models were randomly selected from the archives of the Department of Orthodontics of Federal Fluminense University, Niterói, Rio de Janeiro, Brazil. All plaster model samples were scanned in a plaster model scanner to create the respective digital models. Three examiners defined the arch form on the mandibular arch of these models by selecting the ideal preformed wire shape template on each plaster model or by making a customized digital arch form on the digital models using a digital arch form customization tool. These 2 arch forms were superimposed by the best-fit method. The greatest differences in the 6 regions on the superimposed arches were evaluated. Each examiner presented a descriptive analysis with the means, standard deviation, and minimum and maximum intervals of the differences on the superimpositions. Intraclass correlation coefficient and paired *t* tests were used to evaluate the accuracy of the superimpositions. **Results:** Among the 6 regions analyzed in the superimpositions, the largest differences in the anterior and premolar regions were considered clinically insignificant, whereas the largest differences in the right molar region, especially the second molar area, were considered clinically significant by all 3 examiners. The intraclass correlation coefficients showed a weak correlation in the premolar region and moderate correlations in the anterior and molar regions. The paired *t* test showed statistically significant differences in the left anterior and premolar regions. **Conclusions:** The superimpositions between the arch forms on plaster and digital models were considered accurate, and the differences were not clinically significant, with the exception of the second molar area. Despite the favorable results, the requirement of correcting some software problems may hamper the transition from plaster to digital models. (Am J Orthod Dentofacial Orthop 2018;153:377-86)

The key to the success or failure of an orthodontic treatment is related to the correct positioning of the teeth in the apical base; the arch form must be preserved along with its transversal dimensions. It is also important to maintain a functional balance between the tongue and the circumoral muscle forces.[1]

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Because of the immense variability in dental arch forms among patients, any arch form may not fit every dental arch.[2-6] According to Lee et al,[7] arch form types are influenced by tooth size, arch width, and inclination of the posterior teeth. Paranhos et al[5] found that the most common shape of the mandibular dental arch was oval (41%), followed by square (39%) and tapered (20%).

Since the arch form is an important factor for the stability of the orthodontic treatment, several diagrams or wire shape templates were proposed to facilitate or make more didactic the representation of the mandibular arch shape.[7] The plaster model is a traditionally used tool for diagnosis and treatment planning in orthodontics. It is often used to choose the best diagram that determines the shape of the mandibular arch. However, handling plaster models during wire shape definition might not always be practical; moreover, fractures are common. In such instances, the use of digital models may prove to be a good alternative.

Some studies have proposed arch form definitions with software programs on digital models[4-6,8-13] and photocopied plaster models.[2,3,7,14-18] The first attempts to draw a curve representing the arch forms from radiographs of plaster models using computer software programs were conducted in the late 1960s.[19] However, within the next 2 decades, the use of software programs to define the arch form on photocopies of plaster models had gained popularity in clinical orthodontic practices.[2,14]

Several studies have suggested different methods for the attainment of an optimum arch shape. Some standard forms such as semicircle, ellipse, parabola, catenary curve, and wire shape diagrams including tapered, ovoid, and square forms have been widely used to select prefabricated orthodontic archwires.[10] The application of a Cartesian system onto the photocopies of the plaster models, identifying the x- and y-axes, facilitates the visual evaluation of arch morphology. Another option is the application of sixth-degree polynomials, establishing the 6 most preponderant arch configurations, thereby guiding the orthodontist to visually choose the one that best fits the patient.[3] It was observed that, irrespective of the complexity of the methodology used to determine and choose the dental arch shape, the final choice is subjectively made by the orthodontist in a visual manner.[5]

According to a study by Trivino et al,[3] the arch curve morphology in the anterior region was divided into 8 groups with 3 sizes in each region. A wire shape diagram template for plaster models was created based on this study.[20] Nowadays, customizing the designing of arch forms may provide an option for accurately describing the ideal orthodontic arch form for a particular patient.[6,17]

In clinical orthodontic practice, the selection of preformed archwires is estimated by visual examination or with the aid of arch form templates. The choice of diagrams or wire shape templates in plaster models is a routine procedure used by orthodontists. However, there are doubts about the accuracy of diagrams in digital models when compared with plaster models because of the lack of scientific evidence.[6] Furthermore, since it is a new procedure, some orthodontists are not familiar with the use of diagrams in digital models either in the form of digitized arch form templates or by creating customized digital diagrams using specific software programs.

In this study, we aimed to verify the accuracy of the use of wire shape diagrams on plaster models and customized digital arch forms on digital models based on evaluations by 3 examiners.

MATERIAL AND METHODS

From the archives of the Department of Orthodontics of Federal Fluminense University, Niterói, Rio de Janeiro, Brazil a sample containing 20 pairs of dental plaster models was randomly selected. The following inclusion criteria were used in this study: presence of all maxillary and mandibular permanent teeth up to the second molars, malocclusions with different levels of severity, various arch shapes, and treatments without dental extractions. Exclusion criteria were models of surgical patients and those with severe growth abnormalities. The local ethics committee of our university approved this study on July 22, 2016 (process number 57075116.0.0000.5243).

The following 3 examiners were included in this study: an undergraduate student of dentistry (examiner 1), a postgraduate student of orthodontics (examiner 2), and an orthodontist with more than 10 years of experience (examiner 3). Mucha's arch form individualized diagram, a wire shape diagram template used in the Orthodontics Department of Federal Fluminense University, Niterói, Rio de Janeiro, Brazil,[20] presents 20 arch types printed on transparent acetate that is superimposed on the patient's original plaster model. These arch forms are divided into 5 shapes (1, tapered; 2, flattened; 3, rounded; 4, ovoid; and 5, squared). Each shape has 4 sizes ranging from small to large (Fig 1). This wire shape diagram template was used by the 3 examiners in this study.

All examiners selected the ideal wire shape diagram on each plaster model on the mandibular arch according to the guidelines of Trivino et al.[3] Markings made from visual inspection were used to identify the points corresponding to the mandibular midline, the position of the bracket slots on the labial face of the mandibular canines, and the position of the bracket slots or tubes on the labial surface of the mandibular first molars. After calibration, each examiner chose the diagram that best fit the mandibular arch shape on the plaster models of the sample (Fig 2). Two weeks later, all examiners made a new arch form selection on the same plaster models to evaluate the reproducibility of the method.

Samples of all 20 pairs of plaster models were scanned in a plaster model scanner (R700; 3Shape, Copenhagen, Denmark) to create the respective digital models. Each examiner made a digital arch form diagram on the mandibular arch of each digital model using the digital arch form customization tool in the Ortho Analyzer software (version 1.6.1.0, updated October 30, 2015; 3Shape) according to the same references

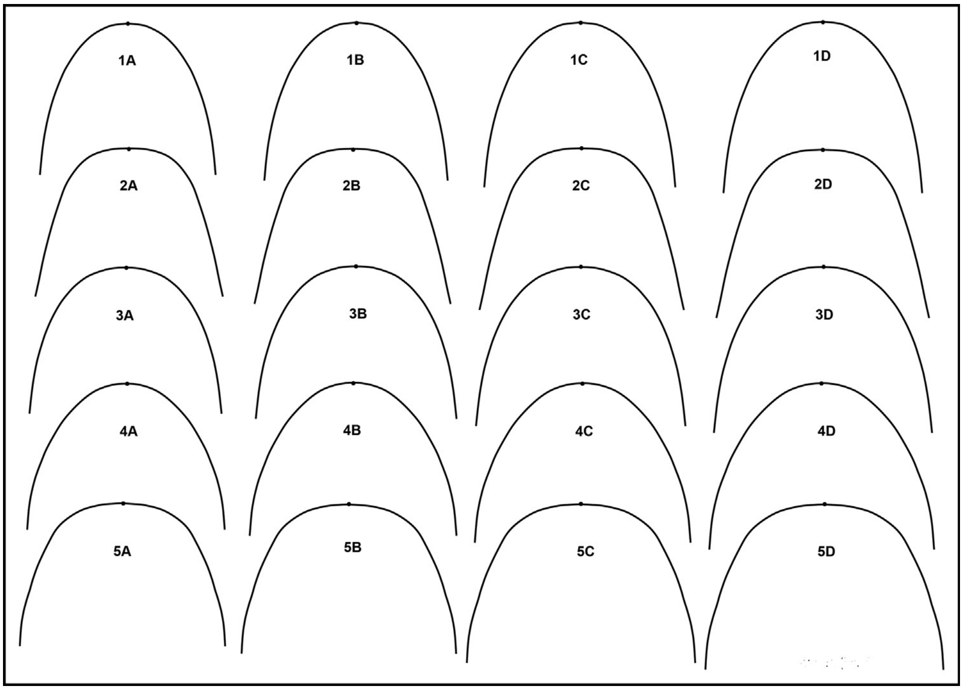

Fig 1. Arch form template used in the study.

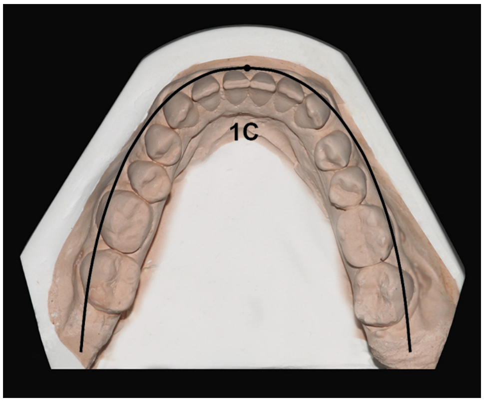

Fig 2. Arch form template with the best fit on the plaster model.

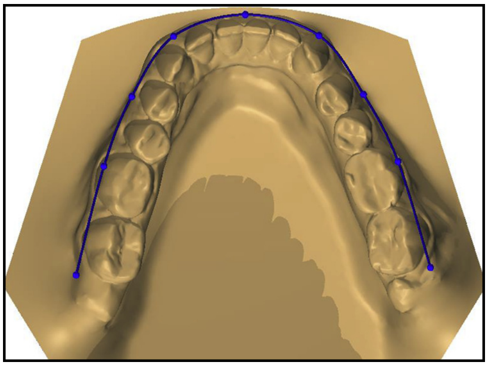

Fig 3. Digital arch form manufacturing using the Ortho Analyzer software.

used to define the arch form diagram for the plaster models. Each digital arch form diagram, superimposed onto the mandibular arch, was individually exported as a report generated in PDF format by the software. The arch form figure was cropped from the report using the software program Photoshop CS6 (Adobe Systems, San Jose, Calif). A difference was noticed in magnification between the arch form size in the PDF report and the actual size of the models. On average, the arch sizes of the samples in the reports were 39.52% larger (range, 39.10%-40.22%) than the real dimensions of the digital models. This magnification was corrected in each digital arch form to standardize a real proportion of 1:1 to enable a comparison by superimposition onto the arch forms selected on the plaster models (Fig 3).

The arch form of each digital model created in the Ortho Analyzer software was superimposed onto the respective arch form diagram selected on the plaster model by each examiner in the first set (Fig 4). The best-fit method, selecting the central region as a reference, was used to superimpose both arch forms using the Photoshop software. Differences between the superimposed arch forms were evaluated by splitting the

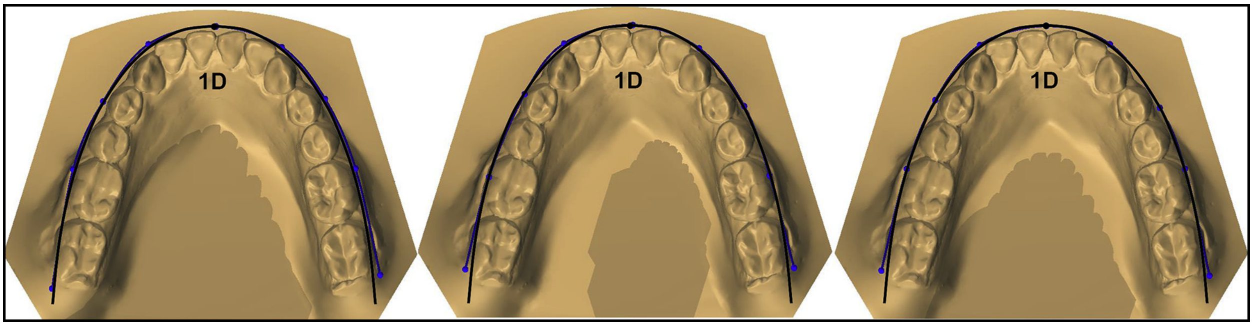

Fig 4. Superimpositions between the arch form template selected on the plaster model (*black line*) and the digital arch form created on the digital model (*blue line*) of a dental model in the sample by examiners 1, 2, and 3, respectively.

diagrams into 6 segments (molar, premolar, and anterior regions on the left and right sides; Fig 5). The wire shape diagram selected for each plaster model was used as the reference. The largest difference between the superimposed arches in each region was calculated using the Photoshop software. An expansion of the customized digital arch form when compared with the wire shape diagram for the plaster model was considered to be a positive value, whereas a contraction of the customized digital arch form was considered to be a negative value.

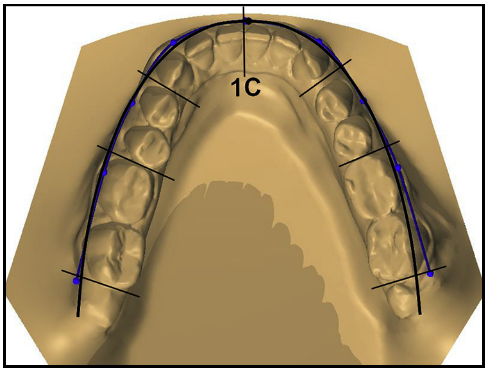

Fig 5. Six regions evaluated in the arch superimpositions between the arch form template selected on the plaster model (black line) and the digital arch form created on the digital model (blue line).

Statistical analysis

Statistical analysis was performed with SPSS software for Windows (version 20.0; IBM, Armonk, NY). The agreement between the 2 sets of wire shape diagrams selected on the plaster models by each examiner was evaluated using the kappa statistical test, at the 5% significance level. Kappa values range from −1 to +1, and according to the literature,[21] +1 establishes perfect agreement; from 0.99 to 0.81 is excellent agreement; from 0.80 to 0.61 is good agreement; from 0.60 to 0.41 is regular agreement; from 0.40 to 0.21 is fair agreement; from 0.20 to 0.00 is poor agreement; and <0.00 is no agreement. The interexaminer level of agreement on the first set of wire shape diagrams selected on the plaster models was also tested by the kappa statistical test at a significance level of 5%. Both intraexaminer and interexaminer agreements for each chosen diagram were evaluated according to the individual arch form and considering only the selected shape (1, 2, 3, 4, or 5).

A descriptive analysis was presented to report the means, standard deviations, and minimum and maximum intervals of the superimpositions of the diagrams of each examiner. The largest differences between the superimpositions of the customized digital arch form on the digital models and the selected arch shape diagram for the plaster model in the 6 selected regions were compared among the 3 examiners using the intraclass correlation coefficient and paired *t* tests to evaluate the accuracy. *P* values <0.05 were considered statistically significant.

RESULTS

Table 1 presents the intraexaminer and interexaminer agreements of the selected wire shape diagrams on the plaster models using the kappa statistical test. The diagrams selected were compared both individually and considering only the selected arch shape. In the case of arch shape selection, intraexaminer tests showed perfect agreement for examiner 3, excellent agreement for examiner 2, and good agreement for examiner 1, whereas interexaminer tests showed perfect agreement between examiners 1 and 3, and excellent agreements between examiners 1 and 2 and examiners 2 and 3. In the case of the individual arch shape diagram, all intraexaminer and interexaminer comparisons had good agreement, with the exception of the intraexaminer agreement for examiner 1, which was considered to be regular.

Table I. Intraexaminer and interexaminer agreement of the selected wire shape diagrams with the kappa statistical test

Parameter	*Arch form diagram (considering only shape)*	*Arch form diagram*
Intraexaminer		
Examiner 1	0.776	0.505
Examiner 2	0.854	0.780
Examiner 3	1.000	0.773
Interexaminer		
Examiners 1 × 2	0.846	0.611
Examiners 1 × 3	1.000	0.716
Examiners 2 × 3	0.846	0.719

Table II shows the descriptive analysis of the largest differences between the arch form diagrams selected for the plaster models superimposed onto the customized digital arch forms on the digital models. The thickness of the line in both diagrams was 0.50 mm. Differences were calculated in the 6 regions, but the molar region on both sides was further divided into first and second molar regions. The differences were evaluated in 2 rankings according to the clinically perceptible level, since a difference of less than 1 mm is compatible with the accuracy of the human eye. Differences of 0 to 1.00 mm were considered clinically insignificant, and those larger than 1.00 mm were considered clinically significant.[8,22]

The largest differences between the diagram superimpositions in the anterior and premolar regions were considered clinically insignificant by all examiners. The largest differences in the right molar region were considered clinically significant by all examiners, whereas those in the left molar region were considered clinically insignificant by examiners 1 and 3, and clinically significant by examiner 2. Considering only the molar regions on the left and right sides, the largest differences in the first molar for both sides were not deemed to be clinically significant by the examiners. However, for the second molar, clinical significance was noted by all examiners on the right side and only by examiner 2 on the left side.

Tables III and IV present the intraclass correlation coefficients and paired *t* test results, respectively, for the largest differences in the superimpositions of the selected arch shape diagrams for the plaster models and the customized digital arch forms for the digital models according to the different arch regions among the 3 examiners. The results showed a weak correlation in the premolar region and moderate correlations in the anterior and molar regions. Considering only the molar regions on both sides, the second molars had a better correlation compared with the first molars.

Paired *t* tests showed statistically significant differences in arch form superimpositions between examiners 1 and 2 and examiners 2 and 3 in the left anterior region, and between examiners 1 and 3 and examiners 2 and 3 in the left premolar region. Considering only the molar regions for both sides, only the left second molar region had statistically significant differences between the examiners. The standard deviations showed large variations in arch form superimpositions among the examiners.

DISCUSSION

The introduction of digital models and the prospect of working with digital documentations can prove beneficial for the orthodontist.[23] However, the transition from plaster to digital models may be hampered by the need to use specific programs to manipulate the digital models; this requires a learning curve for understanding, as well as a financial investment for the software programs.[24]

Arch form definition is a subjective process in the mind of the orthodontist and relies on clinical experience. Some use the alveolar ridge form of plaster models as a reference for the fabrication of archwires, whereas others use the incisal edges and cusp tips, the most facial portion of the proximal contact area, the facial axis point, or the simulated bracket bonding with a glued glass bead as a reference.[3,6,12,13,17,18] General human error can be expected in these subjective analyses, rendering the intraexaminer and interexaminer reproducibilities of these evaluations inaccurate. Hence, the difficulty in classifying the arch shape might result in unreliable classification of intermediate forms, indicating that calibration should be performed among examiners before classification, especially for the shapes of the boundaries.[10] We used the same reference markings described by Trivino et al[3] from visual inspection to the selection of the ideal wire shape diagram for both plaster and digital models. A calibration method between the examiners was applied before the arch form definition on both models.

Despite the subjectivity of the method, the results of our study, which evaluated the agreement of wire shape template selection on plaster models using the kappa statistical test, demonstrated excellent reproducibility of wire shape template selection among the examiners after the calibration process. The agreement in arch form selection was better when only the shape of the diagrams was considered compared with when the individual arch form was considered. A possible explanation for this outcome is that only 5 arch forms considering only the arch shape were compared in contrast to the 20

Table II. Descriptive statistical analysis of the differences in superimpositions between the selected arch shape diagram for the plaster model and the customized digital arch form on the digital models (whole arch and molar regions divided)

	Examiner 1				Examiner 2				Examiner 3			
Parameter	*Mean*	*SD*	*Minimum*	*Maximum*	*Mean*	*SD*	*Minimum*	*Maximum*	*Mean*	*SD*	*Minimum*	*Maximum*
Left molar	0.55	1.26	−1.40	3.30	1.07	1.01	−0.90	3.10	0.87	1.00	−0.90	3.00
Left premolar	0.26	0.64	−1.20	0.90	0.50	0.36	−0.20	1.10	−0.07	0.50	−1.10	0.70
Left anterior	0.33	0.50	−0.80	1.30	0.71	0.40	−0.10	1.50	0.28	0.41	−0.70	0.80
Right anterior	0.24	0.65	−1.60	1.20	0.41	0.50	−0.70	1.40	0.17	0.47	−1.20	0.80
Right premolar	0.52	0.84	−1.70	1.80	0.53	0.43	0.00	1.40	0.36	0.63	−1.30	1.80
Right molar	1.44	1.08	−1.20	3.30	1.37	1.02	−0.30	4.40	1.25	0.64	0.00	2.40
Molar region												
Left first molar	0.08	0.60	−1.40	1.30	0.22	0.51	−0.90	1.00	0.17	0.60	−0.90	1.30
Left second molar	0.33	1.33	−1.40	3.30	1.06	1.01	−0.70	3.10	0.82	1.02	−1.30	3.00
Right first molar	0.79	0.64	−0.70	2.00	0.61	0.60	−0.30	1.90	0.76	0.51	0.00	2.20
Right second molar	1.33	1.17	−1.20	3.30	1.32	1.08	−0.30	4.40	1.20	0.67	0.00	2.40

Table III. Intraclass correlation coefficient between examiners of the differences in the superimpositions between the selected arch shape diagram for the plaster model and the customized digital arch form on the digital models (whole arch and molar regions divided)

Parameter	*ICC*	*95% CI lower bound*	*95% CI upper bound*
Left molar	0.557	0.296	0.772
Left premolar	0.186	−0.072	0.495
Left anterior	0.681	0.457	0.845
Right anterior	0.414	0.138	0.678
Right premolar	0.177	−0.078	0.488
Right molar	0.624	0.380	0.813
Molar region			
Left first molar	0.404	0.128	0.671
Left second molar	0.712	0.499	0.862
Right first molar	0.366	0.090	0.643
Right second molar	0.698	0.479	0.854

diagram types used while considering individual arch forms. Examiner 1 had the worst intraexaminer agreement compared with the other examiners; this might have been because this examiner was an undergraduate student with less experience.

The definition of the arch form diagram in digital models is poorly described in the literature.[6] Therefore, orthodontists have doubts in the management of the wire shape diagrams in patients using digital models. Some software programs can provide this digital arch form using specific tools.[6] With the Ortho Analyzer software version used in this study, it was possible to create a customized digital arch form on the mandibular arch and to overlay a digitized figure of an arch form diagram on the digital mandibular model. We faced some difficulties in both of these cases. It was possible to create a customized digital arch form using the software tool, but the arch size magnification generated in the PDF report was 39.52% larger than the real dimensions of the digital models on average. This magnification should be corrected in each digital arch form to standardize a real proportion of 1:1 for use in clinical practice before it is printed on paper, thus making the process more time consuming. It was not possible to perform the latter arch form definition method using the overlay tool of the software due to the distortion observed when the figure of the arch form diagram was placed on the available grid to perform the overlay on the digital models. Therefore, we used the arch form customization tool in the Ortho Analyzer software to define the digital wire shape diagram, despite the need for magnification size correction to obtain the real proportions of the digital arch form.

All customized digital arch forms defined by the examiners using the software were superimposed with the corresponding arch form diagrams selected on the plaster models in the first set. Several approaches such as the best-fit and the root mean square methods have been proposed to fit the curve of the preformed archwires to the original arch of the patient. In the best-fit method, the archwires are visually compared according to the best fit,[2,6,13] whereas in the root mean square method, a standard mathematic value is evaluated by the similarity between the 2 curves.[11] In this study, we used the best-fit method to perform the superimpositions between the wire shape diagrams selected on plaster models and the customized digital arch forms on digital models by each examiner.

The arch superimposition results showed that the largest differences in the anterior and premolar regions were considered clinically insignificant by all 3 examiners. In the molar region, the differences on the right

Table IV. Paired *t* tests between examiners of the differences in the superimpositions between the selected arch shape diagram for the plaster model and the customized digital arch form on the digital models (whole arch and molar regions divided)

	Examiner 1 vs 2			*Examiner 1 vs 3*			*Examiner 2 vs 3*		
Parameter	*Mean*	*SD*	P *value*	*Mean*	*SD*	P *value*	*Mean*	*SD*	P *value*
Left molar	0.05	1.45	0.88	−0.32	1.04	0.19	0.20	0.76	0.25
Left premolar	−0.24	0.74	0.17	0.33	0.66	0.04*	0.57	0.53	0.00*
Left anterior	−0.38	0.44	0.00*	0.05	0.25	0.38	0.43	0.34	0.00*
Right anterior	−0.17	0.72	0.30	0.07	0.50	0.54	0.24	0.52	0.05
Right premolar	0.05	1.00	0.83	0.22	0.73	0.20	0.17	0.77	0.35
Right molar	0.07	0.71	0.66	0.19	0.88	0.36	0.12	0.83	0.54
Molar region									
Left first molar	−0.14	0.72	0.41	−0.09	0.71	0.58	0.05	0.40	0.62
Left second molar	−0.73	1.06	0.01*	−0.49	0.95	0.03*	0.24	0.42	0.02*
Right first molar	0.18	0.66	0.25	0.03	0.70	0.85	−0.15	0.62	0.31
Right second molar	0.01	0.73	0.95	0.13	0.83	0.49	0.12	0.76	0.49

*$P<0.05$

side were considered clinically significant by all examiners, whereas those on the left were deemed significant by only examiner 2. The mean differences in values were lower in the anterior and premolar regions when the thickness of the arch shape line (0.50 mm) was compared for examiners 1 and 3, and almost for examiner 2, which presented a mean difference larger than 0.50mm only in the left anterior region. The largest differences were found in the right and left molar regions for all examiners (Table II).

The largest differences in the molar region were solely observed in the second molars on both sides; examiner 2 found the largest difference (4.40 mm) among the 3 examiners in the right second molar region in 1 arch superimposition. The largest differences noted in the first molar regions were deemed clinically insignificant by all examiners. In general, the customized digital arch forms were expanded when compared with the arch form diagrams selected on the plaster models (Table II).

The results of this study are similar to those by Nouri et al,[8] who evaluated the differences in recording the coordinates of clinical bracket points between the coordinate measuring machine device and a 3-dimensional laser scanner they developed. The coordinates of clinical bracket points are helpful in drawing a polynomial curve of the dental arch. The results of their study showed an increasing gradient in the differences observed between the methods, moving from the anterior to the posterior teeth. The smallest difference was observed in the central incisors, and the maximum difference was in the molar region, similar to our findings. The differences were slightly varied from 0.2 to 0.9 mm with a mean difference of 0.616 mm, which is considered below the clinically perceptible level. Another study stated that an average difference greater than 1 mm is statistically significant and also assumed to be clinically significant since the arch form tends to return to the original or even a narrower pretreatment form after the retention period.[22]

The results of the arch superimpositions suggest that there are differences between the 2 methods used to define the arch form shape on plaster and digital models, but these differences were not considered clinically significant except for those in the second molar region. The digital arch forms were slightly broader when compared with the arch forms selected on the plaster models, and this expansion was strongly found in the second molar region. A possible explanation is that, in the preformed wire shape templates on plaster models, the orthodontist should adapt the best diagram for a patient, and sometimes the same arch form template can fit well in some areas and not as well in other areas due to its fixed shape. In this study, we noticed a good fit in the anterior and first molar regions. However, in some cases there were slight differences in the premolar region and large differences in the second molar areas, with contraction of the preformed wire shape template when compared with the anatomic arch form on the plaster model. In addition, large differences in the superimpositions in asymmetric arches mainly located in the premolar region were noted by the 3 examiners.

The customized arch form definition for the digital models using the software enables orthodontists to define the diagram in a free manner. Therefore, it is possible to create an arch form that best fits in more areas than those created by the conventional method using preformed wire shape templates on plaster models.

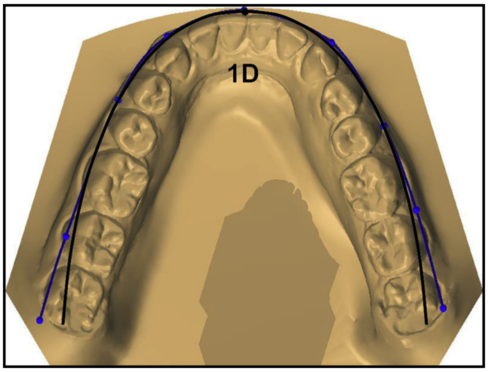

Fig 6. Arch form superimposition showing the differences in the second molar region between the arch form template selected on the plaster model (black line) and the digital arch form created on the digital model (blue line).

In this study, the customized digital arch forms on the digital models represented the anatomic second molar area better when compared with the preformed wire shape diagrams selected on the plaster models (Fig 6). Another advantage of the use of customized digital arch forms is the possibility of creating an arch form according to the virtual setup performed for a patient.

Arch form classification is especially important when using preformed archwires; however, there is some subjectivity in the classification of these commercial arch forms. Although the range of the current commercially available preformed orthodontic archwires does not include diverse dental arch forms,[2,25] orthodontists should select the best archwire among the available types based on the patient's arch form and their clinical expertise.[11] The differences between the superimposed arches were considered clinically insignificant, even though the intraclass correlation coefficient showed a weak correlation in the premolar region and moderate correlations in the anterior and molar regions among the examiners (Table III). These differences can be caused by the subjective method of arch form definition in both plaster and digital models by each examiner, especially in asymmetric arches in the premolar region. However, according to the paired *t* test, few differences between the superimposed arches were found among the examiners in the selected regions. The differences were considered statistically significant only in the left anterior and premolar regions, and in the left second molar region (Table IV). Therefore, despite the differences between the arch form diagrams for the plaster and digital models and among the examiners that are inherent in the methods, they cannot clinically alter the arch forms during the orthodontic treatment. The results suggest that it is safe to use either method to define the arch form for a patient on plaster or digital models.

The definition of the arch form diagram is imperative in maintaining arch dimensions and in guiding the orthodontic treatment. The orthodontist can adjust the curvature of the archwire according to the arch form diagram in all cases, except for the heat activated nickel-titanium arches. Elastic-alloy wires of average shape and size can be used during the leveling and alignment phase, after which it is essential to maintain the dental arch configuration to ensure the success of the orthodontic treatment because of its great influence on stability. Changes in arch form by memory-shape archwires at the beginning of treatment can be corrected by the subsequent use of customized stainless steel therapeutic archwires according to the patient's arch form diagram. Nevertheless, this inconvenience may increase the total treatment time and lead to "round tripping" of the teeth.[26]

Nouri et al[11] determined the magnitudes of differences caused by the available archwires if used as therapeutic archwires for patients with normal occlusion. The differences in their study ranged from 0.48 to 4.68 mm, part of which could be compensated by the thickness of the brackets.[25] In our study, the range of difference between the superimposed arches was −1.70 to 4.40 mm, which was considered quite similar to the aforementioned study. The negative value indicates that the customized digital arch form was contracted when compared with the arch form diagram on the plaster model, whereas positive values indicate the opposite.

The arch form tool in the Ortho Analyzer software enabled us to define the form of the maxillary arch from the ideal mandibular arch using a coordination of 2.0 mm overjet between the arches (Fig 7). Therefore, both mandibular and maxillary arches can be defined in the software to treat a specific malocclusion. However, according to the literature, there might be differences in coordination between the maxillary and mandibular arches. A study showed a tendency to a decreased overjet from the anterior segment (2.3 mm) to the posterior one (2.0 mm).[13] These differences could be compensated by wire bending in the finishing stage, the production of new brackets with individualized bracket base thickness, or the individualization of resin thickness under the bracket base for indirect bonding.[13]

We agree with other authors that it is wise to establish the arch form diagram to conform to the archwires during orthodontic treatment because of the tendency of the arch form to return toward the pretreatment shape after retention.[17,18] The greater the treatment change, the greater the tendency for postretention change, but minimizing treatment change is no guarantee of

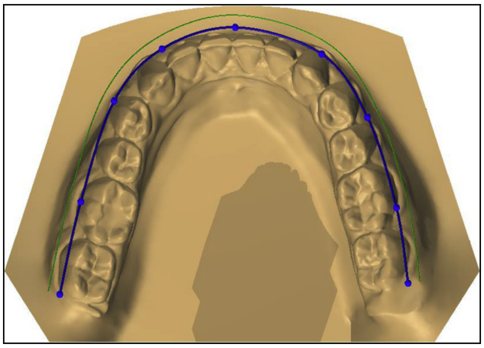

Fig 7. Mandibular digital arch form (*blue*) and maxillary digital arch form (*green*) using an overjet of 2 mm in the Ortho Analyzer software.

postretention stability,[18] because growth can be responsible for postretention changes in mandibular arch forms that were not altered during orthodontic treatment.[17] Nevertheless, with the continuing development of computer-assisted analysis, the approach of custom-designed arch forms may provide the optimum solution for accurately describing the ideal orthodontic arch form in each patient.[2] Computer programs for diagnostic purposes can provide accurate data to define complex arch form patterns easily.[6,17] It is also possible to define an ideal arch form for a patient according to the respective virtual setup.[24]

The results of this study showed that the methods used to define arch form on plaster and digital models were accurate with no clinically significant differences, with the exception of the second molar area, which was better represented on the digital models. With the increasing use of digital models in orthodontic clinical practice and their consequent advantages, the digital method of arch form definition can substitute for the conventional method used on plaster models. However, despite the favorable results, the requirement of correcting some software problems, such as the magnification of the arches on the printed report, can hamper the transition from plaster to digital models.

Several software programs can define the facial axis point of the tooth, perform a virtual setup, and define the bracket placement on digital models, but alignment of the bracket slots on the teeth instead of the facial axis points is required for precise arch coordination.[13] The evaluation of the relationship between the positions of digital brackets and wires in the virtual setup could help clinicians to understand possible "round tripping" tooth movement in the finishing stages. Hence, in the future, every orthodontic clinic could be equipped with an intraoral scanner, a software program to perform a virtual setup to define the wire shape diagram and the position of the brackets, an arch form molding machine to create the archwires, and a 3-dimensional printer to manufacture indirect bonding trays to place the brackets.

CONCLUSIONS

The methods used to define arch form are subjective, but the superimpositions between the arch forms on plaster and digital models were considered accurate in this study. Moreover, the differences were not clinically significant, with the exception of the second molar region. The agreement of arch form definition on plaster models among the 3 examiners was excellent when arch shape was considered and good when individual arch form was considered. The digital method of arch form definition can substitute for the conventional method used on plaster models. However, despite the favorable results, the need to correct some software problems can hamper the transition from plaster to digital models.

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