Original Article

Agreement of the clinician's choice of archwire selection on conventional and virtual models

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ABSTRACT

Objectives: To compare archwire selection on dental casts with archwire selection using a three-dimensional (3D) software program (OrthoAid) and assess agreement between clinicians.

Materials and Methods: The best-fitting archwires were selected for dental casts of 100 patients with malocclusion using two approaches by three orthodontists. The first method was to visually determine the fitness of five preformed nickel titanium archwires to the arch form on a dental cast (subjective method). The second method was archwire selection on a virtual image of the same cast by means of 3D software (objective method). Agreement between selections performed by the orthodontists was calculated using Kappa statistics. The accuracy of fit of the archwires to the curves fitted to the arch form was also calculated or reversely assessed by means of the root mean square (RMS) for both methods using the Dahlberg formula.

Results: The mean RMS of the distances between the patient arch forms and the archwires for the subjective method was 1.163–1.366 mm. The agreement of selections between orthodontists was 42%–58% (Kappa ranged from .074 to .382). Using the 3D software (objective method), the mean RMS decreased to 0.966–1.171 mm, and agreement increased to 47% to 84% (Kappa ranged from .444 to .747).

Conclusions: The use of 3D computer software for archwire selection in patients with malocclusion provided better adaptation and interexaminer reliability. (*Angle Orthod.* 2019;89:597–604.)

KEY WORDS: 3D modeling; Arch form; Dental arch; Digital model; Malocclusion; Nickel titanium archwire

INTRODUCTION

Dental arch form is primarily determined by the shape of the supporting alveolar bone and can be modified by muscular and functional forces following eruption of the teeth.[1,2] The arch form influences function and esthetics as well as occlusion.[3]

It is generally advised to maintain the patient arch form during fixed orthodontic treatment. Orthodontic archwires play a significant role in expansion of the dental arch.[4] This is more important during the use of nickel titanium (NiTi) archwires, as these wires are not easily customizable[1,5] and may contribute to arch form

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Accepted: January 2019. Submitted: May 2018.
Published Online: March 6, 2019

development during early stages of treatment.[6] Preformed NiTi archwires are available in various shapes and sizes, and their average intercanine width could exceed the natural mandibular intercanine width by almost 6 mm.[7] Thus, it is important to select prefabricated NiTi archwires that are similar to the patient arch form to minimize changes and reduce possible relapse.[8] The therapeutic arch form should be designed by considering the original arch form of the patient and treatment objectives.[9]

A survey by McNamara et al.[6] revealed significant variation in archwire selection methods among orthodontists. Most orthodontists selected archwires subjectively by visual assessment of the adaptation of the archwires to the facial axis or facial surface of the teeth, incisal edges and cusp tips, or the facial portion of the proximal contacts.[5,10–12] One study showed wide variation in the dimensions of working archwires fabricated on identical dental casts using subjective assessment among 30 clinicians.[13] McNamara et al.[6] raised a question regarding the possibility of using digital models for accurate archwire selection. Computer software can act as a decision support system to increase agreement in treatment results.[14]

To choose the archwire objectively, a mathematical method describing the arch form is required. Methods such as the cubic spline function,[15] beta function,[2] parabola,[16] and fourth-order polynomial functions[9,17] have been used. AlHarbi et al.[18] compared these methods and revealed that the fourth-order polynomial equation represented the most appropriate function for describing the arch form because of its naturally smooth curvature.

Some investigators have evaluated arch form determination and/or archwire selection using computer software.[9,17,19,20] Camardella et al.[19] used midline, canine, and first molar bracket slot points for making digital arch form diagrams and compared them with arch form diagrams on dental casts. Arai and Will[17] used incisal edges, canine cusp tip, and buccal cusps of the premolars and molars for drawing the best-fitted polynomial curve. Dahiya et al.[20] used the best-fitted polynomial curve generated from the facial axis points of all teeth as the patient arch form to find arch asymmetry following unilateral extraction. Nouri et al.[9] used a three-dimensional (3D) computer software to form a best-fitted polynomial curve based on clinical bracket points (CBPs) in normal occlusion cases. They chose the best archwire by comparing the root mean square (RMS) of the distance of available archwires and polynomial curves.

A polynomial curve adopted on the CBPs of the digital model could represent the arch form. It is possible to compare the distance of all commercially available archwires to this polynomial curve and choose the one with the least discrepancy using the RMS method for comparison of the curves.[9] This method could improve current inconsistencies in landmark and archwire selection methods.[6] The aim of the current study was to assess the agreement between clinicians in archwire selections on actual casts of patients with malocclusion by visual assessment and on their virtual casts using the proposed polynomial curve based method.

Table 1. Inclusion Criteria

Inclusion Criteria
Angle Class I, II, and III malocclusion
Permanent dentition
All teeth were present and had normal shape and size (not considering third molars)
No supernumerary tooth
>4-mm crowding in each jaw
Patient documents were available

MATERIALS AND METHODS

Patients

Sample size calculation was performed using the "Power5Cats" function of the R package KappaSize.[21] Considering the agreement level in a previous study,[9] a sample size of 100 subjects was calculated to test a Kappa of .7 against an unfavorable Kappa of .5 with 88% power at a 5% significance level. These previously treated patients were included based on inclusion criteria (Table 1) and were selected from the orthodontic department archives.

Archwires

Five orthodontic 0.016 × 0.022-inch NiTi archwires were chosen because they represented various types of arch forms: American Orthodontics Form I, Force I (American Orthodontics, Sheboygan, Wis); American Orthodontics, Form II, Force I (American Orthodontics); DB Orthodontics, Euroline (DB Orthodontics, Silsden, UK); Ortho Organizer, NiTi Form (Ortho Organizers, Carlsbad, Calif); and OrthoForce, Trueform I (G&H Orthodontics, Franklin, Ind). These archwires were scanned with a laser scanner (Minolta c452; Konica Corporation, Tokyo, Japan; Figure 1).

Subjective Selection of Archwire

Three orthodontists with 1, 7, and 25 years of clinical experience were asked to choose the best-fitting archwires for each patient independently by manually adapting them to maxillary and mandibular pretreatment dental casts and visual comparison for best fit.

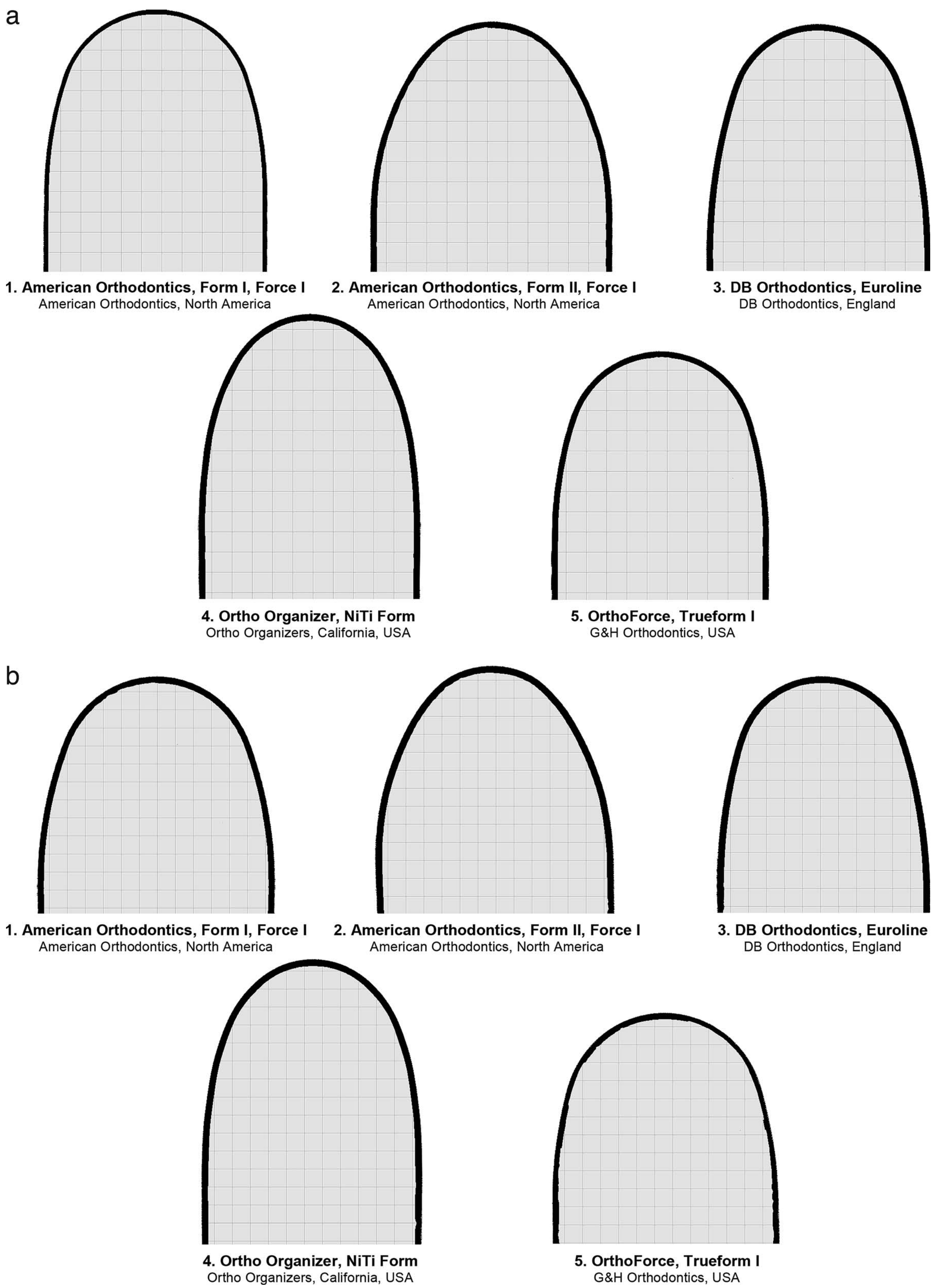

Figure 1. Images of selected (a) mandibular and (b) maxillary archwires.

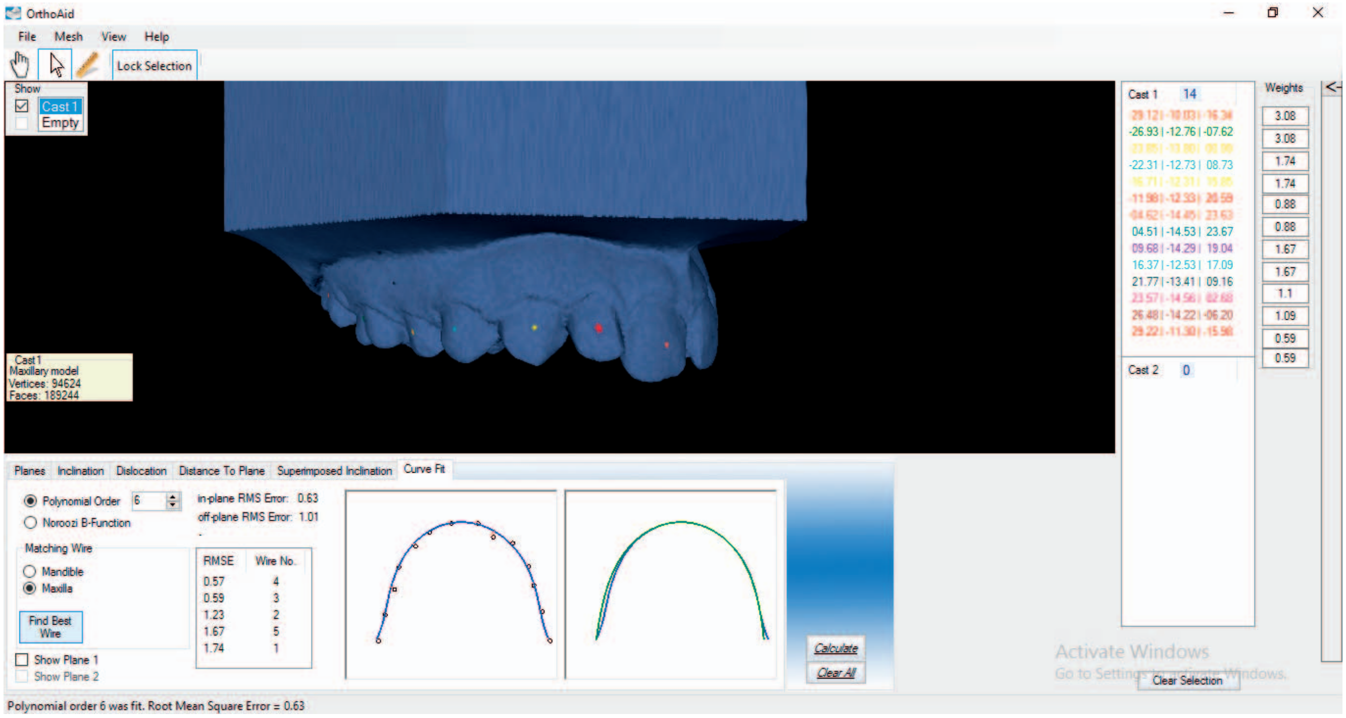

Figure 2. A sample archwire selection using OrthoAid software.

Digitization of Dental Casts

The maxillary and mandibular dental casts were digitized using a 3D laser scanner (Maestro 3D Dental Scanner; MDS400, AGE Solutions, Potedera, Italy). The scans were transferred to OrthoAid, a computer software application that was developed for orthodontics and used in previous studies.[22] The interexaminer and intraexaminer reliability of archwire selection using OrthoAid computer software were calculated to be .991 and .995, respectively,[9] which indicated excellent reliability.

Objective Selection of Archwire

The same orthodontists selected archwires with the aid of OrthoAid. First, the reference points indicating CBP were selected on the buccal surface of each tooth. Then, the software calculated a plane that had the least distance on the *z*-axis using principle component analysis. The CBP points are attachment points of the bracket in a clinical setting[23] and were determined according to the guideline for preadjusted appliances.[24] Next, a sixth-degree polynomial curve was fit to this plane by optimizing the smallest RMS error. This polynomial curve was considered to be the patient arch form.[9] The software computed the RMS of each scanned archwire for the defined arch form and sorted the archwires based on their adaptations (Figure 2). The best-fitting archwire that had the smallest RMS was chosen as the best for the given cast, and the others were ranked based on the RMS measurements.

To assess intraexaminer reliability of digital archwire selection, one orthodontist repeated the archwire selection for 12 randomly selected digital study casts after 4 weeks.

Statistical Analysis

Agreement among the orthodontists was calculated using the Kappa coefficient and intraclass correlation coefficient (ICC) at a 95% confidence interval (CI). The mean distance of each archwire to the patient arch form in each comparison was calculated using the Dahlberg formula. Data were analyzed using SPSS software (version 18; SPSS, Chicago, Ill) with a significance level of .05.

RESULTS

The archwires with the highest frequency of selection by each orthodontist in both methods were numbers 3 and 4 (Figure 3). The mean RMS of the archwire-to-arch distance using the subjective method was 1.163–1.366 mm. This distance decreased to 0.966–1.171 mm using the objective method (Table 2). Intraexaminer reliability of digital archwire selection as evaluated by ICC was .818 ($P = .004$) and, by Kappa statistic, was .423 ($P = .007$).

Using the subjective method, the agreement of selections between orthodontists 1 and 2, orthodontists

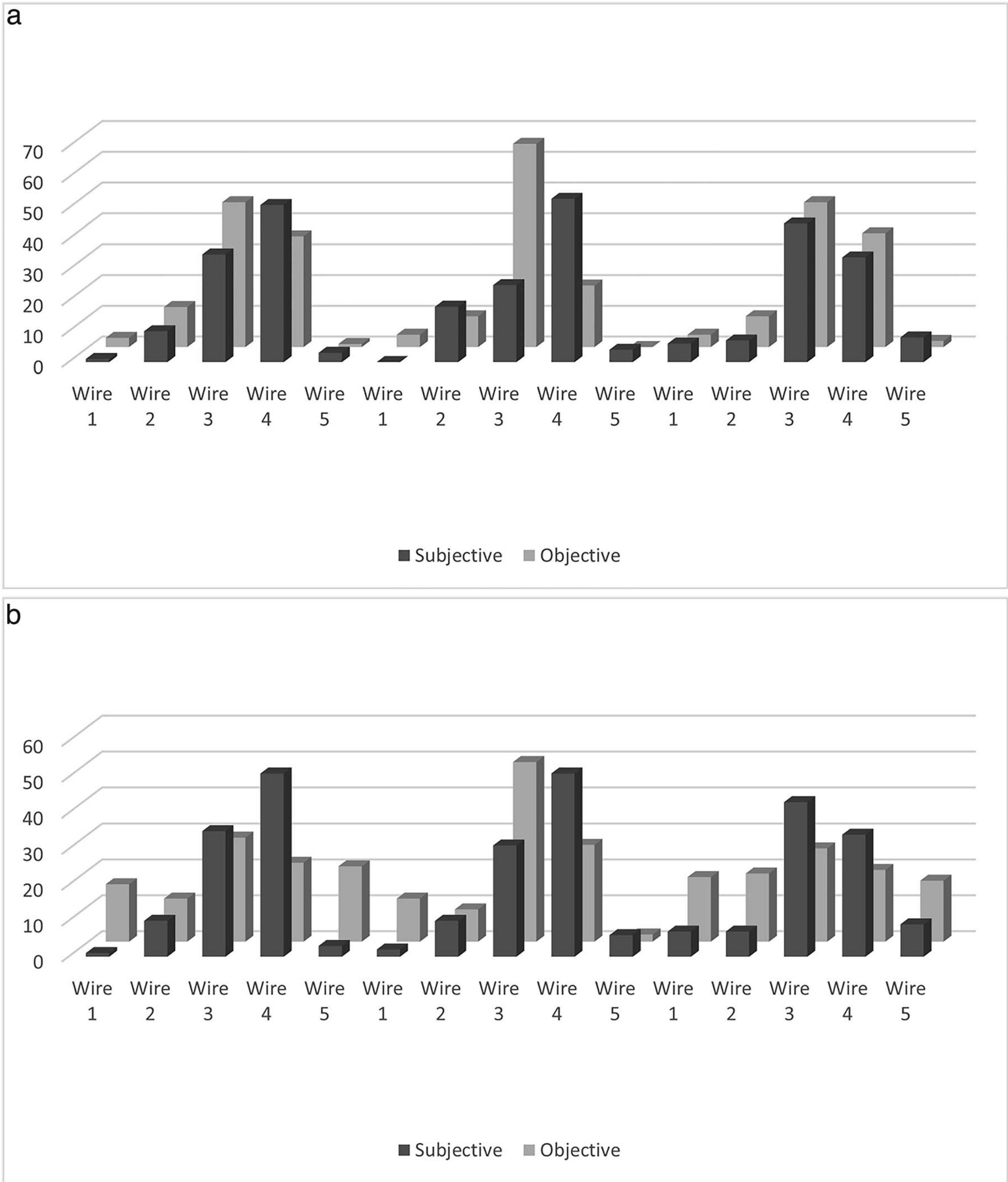

Figure 3. The percentage of each of the archwires selected by the three orthodontists using subjective and objective methods in the (a) maxillary arch and (b) mandibular arch.

1 and 3, and orthodontists 2 and 3 were 57%, 39%, and 42% for the upper arch and 54%, 43%, and 58% for the lower arch, respectively. While using the objective method, the rates were 68%, 84%, and 72% for the upper arch and 47%, 77%, and 57% for the lower arch, respectively.

Agreement among orthodontists was .074 to .382 subjectively and .444 to .747 objectively based on the Kappa statistics (Table 3). The overall agreement among these orthodontists based on the RMS calculated by means of ICC was .428 for the upper arch and .237 for the lower arch ($P < .001$) using the subjective method. The corresponding values for the objective method were .394 and .334, respectively ($P < .001$). The correlation coefficient of the range of agreement between pair comparisons of the orthodontist selections varied from .056–.527 to .178–.568 using the subjective and objective methods, respectively (Table

Table 2. Mean and Standard Deviation (SD) of the RMS of the Distance Between Arch Form Fitted to Clinical Bracket Points and Selected Archwire (Sample Size: 100)

Method	Jaw	Orthodontist	Mean	SD	Min	Max
Subjective	Maxilla	1	1.196	0.601	0.37	4.03
		2	1.366	0.581	0.40	2.94
		3	1.276	0.607	0.27	3.39
	Mandible	1	1.195	0.560	0.26	3.07
		2	1.219	0.495	0.32	2.62
		3	1.163	0.530	0.21	3.10
Objective	Maxilla	1	1.021	0.549	0.27	3.97
		2	1.171	0.507	0.28	2.51
		3	0.966	0.527	0.27	3.39
	Mandible	1	1.003	0.553	0.25	3.07
		2	1.123	0.511	0.26	2.58
		3	0.966	0.518	0.21	2.65

3). To depict the number of numerical discrepancies between orthodontist selections, the RMS of the differences among them was calculated. Using the subjective method, the mean discrepancy among orthodontists was .380–.502 mm, which decreased to .353–.490 mm using the objective method in pair comparisons (Table 3).

Table 4 shows the percentage of agreement of archwire selections between methods for each orthodontist. The percentage of similarity between selections of each orthodontist using the two methods was 47%, 31%, and 36% for the maxillary and 32%, 47%, and 34% for the mandibular arch. It was apparent that, while the choices were not very similar between techniques (Kappa .018–.237), the correlation coefficient (ICC) was relatively high ($r = .700$–$.950$; Table 4).

DISCUSSION

In a clinical situation, orthodontists should select the most appropriate archwire for the patient arch form and treatment plan to align and level the teeth. This step is sometimes neglected as the orthodontists might assume that light NiTi archwires will not alter arch width. However, clinical trials have revealed significant arch width change during alignment and leveling using prefabricated archwires.[25–27] In addition, correction of this arch form using customized stainless-steel wires will increase the total treatment duration and cause "round tripping" of the teeth.[1]

Preserving the arch form also affects stability of the treatment results.[28] The intercanine width of each patient is determined by muscular balance, and any unintended expansion in this region could cause instability.[28] This could be more problematic in non-extraction cases and cases with severe crowding.[29] Previous studies performed on individuals with normal occlusion indicated that further evaluation of archwire selection in patients with malocclusion is necessary, because most of them would not visit an orthodontic clinic with well-aligned teeth. On the other hand, selecting a therapeutic arch as the basis for setup manufacturing is the first step toward correcting deformations on the initial dental arch.

RMS is a reliable method for comparing two curves and has been used in previous studies for quantification of subjective data.[9,30] Subjective archwire selection was done by visually comparing each archwire to the patient study cast. In the current study on malocclusion cases, the mean RMS of the selected archwires to the arch form were 1.163–1.366 mm, and the difference among the three orthodontists was less than 0.5 mm using Dahlberg's formula (Table 3). The agreement among selection of archwires by the three orthodontists was low (Kappa $\leq$.382). This finding was in agreement with a previous study on 36 normal occlusion individuals, which showed that subjective archwire selection by three orthodontists had a mean RMS of 1.432–1.745 mm and a difference of 0.241–0.351 mm.[9] In that study, the authors found low agreement among orthodontists using subjective archwire selection (Kappa .238–.450). They stated that this discrepancy could cause up to a 3.5-mm discrepancy in the final positions of the teeth, which occurs mostly in the premolar region. However, another study showed better agreement (Kappa .611–.719) among three orthodontists for selection of archwires for 20 mandibular plaster models.[19]

The objective method can be used for selection of the most appropriate archwire for each patient. One objective approach is to choose the archwire by performing measurements on patient dental casts.[31]

Table 3. Agreement Between Orthodontists Using Subjective and Objective Methods for Archwire Selection

		Kappa		ICC				Dahlberg, mm	
Method	Orthodontists	Maxilla	Mandible	Maxilla	*P* Value	Mandible	*P* Value	Maxilla	Mandible
Subjective	1 and 2	NA	.257	.352	<.001	.098	.164	.490	.502
	1 and 3	.074	.144	.486	<.001	.527	<.001	.437	.380
	2 and 3	NA	.382	.455	<.001	.056	.291	.447	.500
Objective	1 and 2	NA	.448	.178	.037	.231	.010	.490	.474
	1 and 3	.747	.710	.554	<.001	.568	<.001	.360	.353
	2 and 3	NA	.444	.448	<.001	.190	<.001	.404	.480

Table 4. Agreement Between Subjective and Objective Archwire Selection for Each Orthodontist

	Kappa		ICC				Dahlberg, mm	
Orthodontist	Maxilla	Mandible	Maxilla	*P* Value	Mandible	*P* Value	Maxilla	Mandible
1	.170	.113	.700	<.001	.913	<.001	.338	.213
2	NA	.237	.908	<.001	.950	<.001	.215	.131
3	.018	.153	.780	<.001	.904	<.001	.332	.214

Although measurement of the intercanine distance is beneficial for cast analysis,[17] archwire selection using this single variable could result in up to 6 mm of discrepancy.[1] The addition of other parameters, such as intermolar width[1] and arch perimeter,[16] could increase precision. Arai and Will[17] measured the intercanine and intermolar width of 3D scanned dental arches to be used for a polynomial equation. In the current study, the arch form was drawn using the polynomial curve, which had the least distance to all 14 CBPs from the left second molar to the right second molar. This method, which uses several reference points, seems to be more precise.[9]

Using the objective method, agreement among orthodontists was relatively better (Kappa $\leq$.747), and the RMS of archwire to arch form distance decreased (0.966–1.123 mm). Only five archwire forms were included in this study because an increase in the number of selections would have increased the variability of selections, especially in the subjective method. This was a limitation of this study. Comparison of the similarity of archwire selection by each orthodontist using subjective and objective methods revealed that they changed their choices more than half the time when the software revealed patient arch form and RMS.

The archwires selected using the objective method showed less discrepancy with the patient arch form than the subjective method (0.131–0.338 mm less error). A study using the same methodology in 36 patients with normal occlusion showed that the use of computer software for archwire selection increased the level of agreement between orthodontists (Kappa = .715) and produced a lower RMS (1.348–1.666 mm). The study also showed less discrepancy using the objective method (0.229–0.562 mm less error).[9] Lee et al.[32] objectively determined an arch form using arch depth, intercanine and intermolar width, anterior curvature, and arch width ratio. They reported 0.111 mm of interexaminer error using the RMS of distance between arch forms. In another study, the interexaminer reliability of arch width measurements on 3D virtual models was greater than 0.90.[33] The difference between arch width measurements performed on plaster and digital models was 0.22–0.61 mm. In a more recent study, Camardella et al.[19] showed that archwire selection for the mandibular arch using computer software had a 0.17–1.44 mm difference compared with wires selected subjectively on plaster models.

The software used in the current study was a 3D cast analysis software, which performs several functions and measurements. Following determination of CBPs by the operator, the software is able to draw a polynomial curve of different degrees and calculate the RMS of each archwire. Previous studies used fourth-degree polynomial curves for dental arches with normal occlusion.[9,17,18] In the current study, however, different polynomial degrees were evaluated, and it was found that a sixth-degree polynomial curve was a better choice for dental arches with malocclusion. Similar methods have been used by other researchers.[34–36] It has been reported that polynomials with more than six degrees produced distorted and irregular arches.[34]

CONCLUSIONS

- Using the objective method, orthodontists were able to choose an archwire with better fit than by using a subjective method.
- Agreement of selections among orthodontists also increased with the objective method.

ACKNOWLEDGMENTS

This research was funded by the Dentofacial Deformities Center, Research Institute of Dental Sciences, Shahid Beheshti University of Medical Sciences, and was part of the postgraduate thesis of Dr Sahar Hadadpour supervised by Professor Mahtab Nouri.

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