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ORIGINAL ARTICLE

Evaluation of the fit of preformed nickel titanium arch wires on normal occlusion dental arches

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KEYWORDS

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Abstract *Aim:* To determine the fits of preformed nickel titanium (NiTi) archwires on dental arches with normal occlusion.

Methods: Forty sets of upper and lower plaster models were obtained from men and women with Class I occlusions. Preformed 0.016″ × 0.022″ NiTi archwires from Rocky Mountain Orthodontics (RMO), 3 M Unitek, Ormco, and Dentaurum were evaluated in terms of their fits on dental arches from male, female, and combined cases. Data were analyzed by using fourth- and sixth-order polynomial equations, analysis of variance (ANOVA), and the Duncan post hoc test.

Results: In the upper arches, the best fit and least error were obtained with RMO Ovoid and Ormco Orthos Large archwires for male cases, but with 3 M Orthoform LA archwires for female and combined cases. In the lower arches, the best fit and least error were obtained with Ormco Orthos Large for male cases, with 3 M Orthoform LA and RMO Normal for female cases, and with 3 M Orthoform LA, RMO Normal, Ormco Orthos Large, and Ormco Orthos Small for combined cases. When both dental arches were matched, Ormco Orthos Large was the best wire for male cases. 3 M Orthoform LA was the best wire for female and combined cases.

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Conclusions: Using an archwire form with the best fit to the dental arch should produce minimal changes in the dental arch form when NiTi wires are used and require less customization when stainless-steel wires are used.

1. Introduction

Achieving a stable, functional, and esthetic arch has long been the primary objective of orthodontic treatment. A key aspect in achieving these goals is the identification of a suitable arch form for each case. Preservation of the original arch form and size plays an important role in ensuring the long-term stability of orthodontic treatment results (Shapiro, 1974; Felton et al., 1987; DeLa Cruz et al., 1995). Felton et al. (1987) examined pretreatment, posttreatment, and postretention dental casts of 15 Class I and 15 Class II nonextraction orthodontically treated patients. When orthodontic treatment changed the arch form, the results frequently were unstable and relapsed to the pretreatment state. They concluded that in many cases, arch forms must be customized to obtain long-term stability (Felton et al., 1987). DeLa Cruz et al. (1995) examined the casts of 45 Class I and 42 Class II Division 1 malocclusion cases. Patients underwent extraction of the four first premolars and were followed for at least 10 years after retention. The arch form rounded during treatment, followed by a change to a more tapered form during the postretention period. They concluded that the arch form tends to return to the pretreatment shape after retention.

When a preformed archwire is used in orthodontic treatment, the form of the treated dental arch is altered to match the form of the wire. However, because of the wide variation in arch forms among humans, there is no consensus on the optimal dental arch form to be achieved as the result of treatment. Hence, it is critical to select the appropriate archwire form for each case. An important issue that arises in orthodontic practice regards the selection of the appropriate form from different archwire blanks. Modern orthodontic mechanics consists of archwires of various types, shapes, and sizes according to different manufacturer specifications. With the advent of highly elastic preformed nickel titanium (NiTi) wires, clinicians began to introduce large cross-section archwires in the early stages of orthodontic treatment.

Braun et al. (1999) superimposed 33 popular NiTi preformed archwire and bracket assemblies on maxillary and mandibular normal occlusion arch forms with the use of the Beta function. They found that the forms of the preformed wires did not emulate the natural human arch form. Specifically, all of the arch widths (measured at the canines and first molars) determined by the preformed wires were greater than the arch widths of the natural human arch form (Braun et al., 1999).

It would be beneficial to have archwires with a limited number of forms and sizes that resemble most patient arches. This scenario would enable the original arch form to be preserved as much as possible during the initial stages of treatment when NiTi wires are used, and would minimize the need for wire customization in the final stages of treatment when large stainless-steel (SS) wires are introduced. The aim of this study was to evaluate the fits of various commercially available preformed archwire designs in Saudi men and women having normal occlusion arches.

2. Materials and methods

2.1. Study sample

Upper and lower plaster dental models were obtained for 40 adult Saudi subjects (20 men, 20 women; age: 18–25 years) with Class I normal occlusion. Male samples were obtained from cadets at King Abdulaziz Military Academy. Female samples were obtained from female dental students and interns at King Saud University, College of Dentistry. Subjects with Class I occlusion were chosen because the preponderance of malocclusions is corrected to this Angle classification. Class I occlusion was defined as the presence of bilateral Class I molar and canine relations, overbite/overjet between 2 and 4 mm, no crowding or spacing exceeding 2 mm, no rotated teeth, and no anterior or lateral cross-bite (Ferrario et al., 1997, 1999). Subjects were excluded if they had undergone previous orthodontic or prosthetic treatment, proximal or extensive occlusal restorations involving the cusp tips, or if they had obvious incisal or cuspal attrition, tooth fracture, ectopically erupted or supernumerary teeth, deciduous teeth, congenitally missing teeth, or extracted teeth (excluding third molars) (Ferrario et al., 1997, 1999).

Preformed 0.016” × 0.022” NiTi archwires of four popular brands were evaluated in terms of their arch form and size on a normal occlusion sample. The archwires tested were as follows:

(1) Rocky Mountain Orthodontics (RMO) pentamorphic system: Normal, Tapered, Ovoid, Narrow Tapered, and Narrow Ovoid.
(2) 3 M Unitek (3 M): Orthoform I (tapered), Orthoform II (square), Orthoform III (ovoid), Orthoform LA, and Standard.
(3) Ormco: Broad Large, Broad Small, Orthos Large, Orthos Small, Tru-Arch Medium, and Tru-Arch Small.
(4) Dentaurum: Normal and American.

2.2. Model/wire digitization and curve fitting

Imaging methods and digitization software were developed and tested in a previous study (Al-Harbi et al., 2008). Because the main objective of the current study was to compare preformed archwires to dental arch forms, the arch forms were defined according to the respective bracket positions on the teeth. Clinically, brackets are positioned on teeth according to a defined midpoint on the facial axis of the clinical crowns (FA point). The FA point divides the most prominent point of the central lobe of all clinical crowns except the molar teeth.

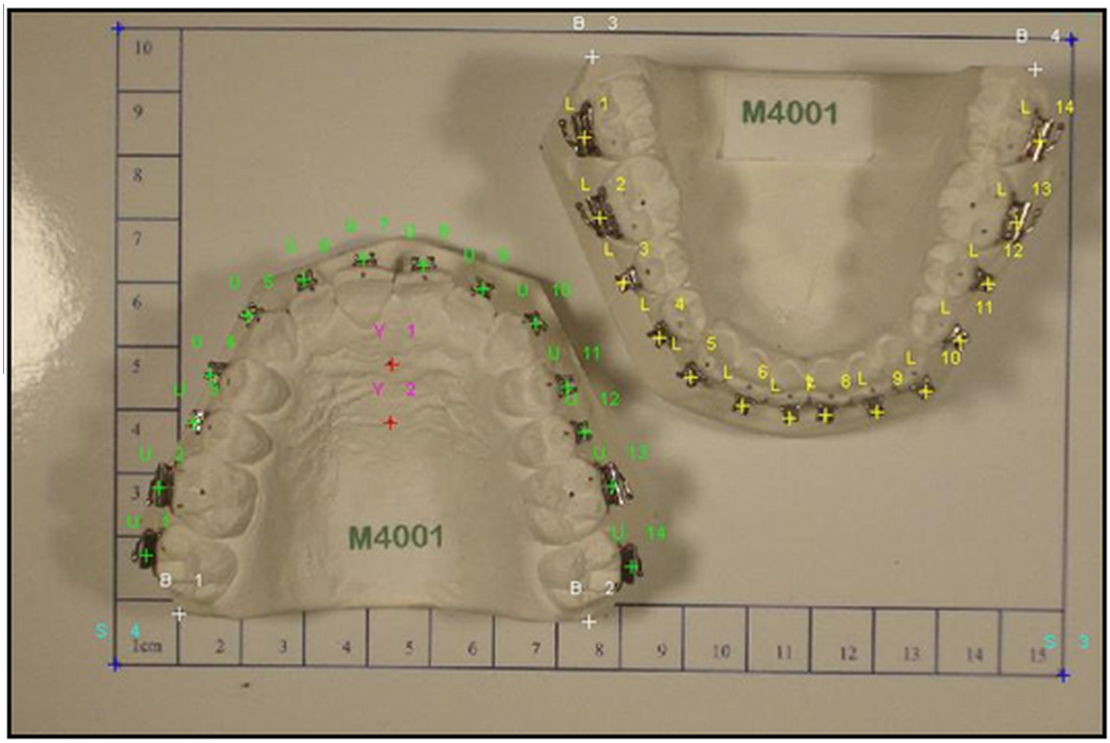

Figure 1 Orthodontic brackets and captured landmarks bonded on the model.

For molars, the FA points are determined on the mesiobuccal groove (Fig. 1) (Fujita et al., 2002).

To digitize the models, 14 points, each representing the midpoint of the bracket or tube on the tooth, were recorded on each arch. To mark the upper anatomical y-axis, two points on the midpalatal raphe were captured (Ferrario et al., 1997; BeGole, 1980). Several MATLAB computer programs were created and used to capture landmarks. To eliminate the effect of tooth irregularities in the dental arches, the 14 landmark points representing the teeth were fitted with a mathematical descriptor that produces a smooth and representative curve. Fourth- and sixth-order polynomials were sufficiently flexible to approximate the dental arch form. These mathematical functions are monotonic in nature, produce a regular curve, and distribute the error evenly around the arch.

Preformed wires were scanned directly by using a high-resolution digital scanner (HP Scanjet 3570c) with a white background. Red markers, located $\sqrt{(10^2 + 15^2)}$ cm apart, were placed on the white background and used as scale points to convert pixels into the proper measurement units (in this case, cm).

2.3. Evaluating the fit of the wires

To evaluate the fit of the wires on the dental arches quantitatively, each wire was superimposed on each dental arch. The error in fit was computed as the difference (in cm) between each landmark on the arch form and the corresponding point on the wire along the line-joining point (s1) and the corresponding landmark (Fig. 2). Computed errors were considered negative if the wire was to the inside of the arch form and positive otherwise.

Absolute values of the 14 measurements were summed and divided by 14, to calculate the mean absolute error (MAE) per tooth. Absolute values were used because we are mainly concerned with the total difference between the arch and the wire. Maintaining the negative sign in the calculation would result in a mean value that does not adequately describe the overall difference. An MAE close to zero indicates that the wire has a good fit to the arch, whereas a high MAE indicates a greater difference between the wire and the arch (and, thus, a poorer fit).

2.4. Statistical analysis

Descriptive statistical analysis was performed to find the mean, the standard deviation, standard error, and upper and lower bounds of the 95% confidence interval of the mean, and the minimum and maximum results for each of the 18 wires. Analysis of variance (ANOVA) was used to compare the MAEs of the 18 wires. A P value less than 0.001 was considered statistically significant. After MAEs were ordered in an ascending manner, the Duncan post hoc test was applied to group the wires into statistically homogenous subsets.

Accuracy of the digitizing software was tested in a previous study (Al-Harbi et al., 2008). To test the examiners' reliability of digitization, 10 pairs of upper/lower models were randomly selected, digitized twice, fitted by a polynomial curve, and superimposed on each tested archwire. The MAE between the wire and the tested arch was calculated. Correlation

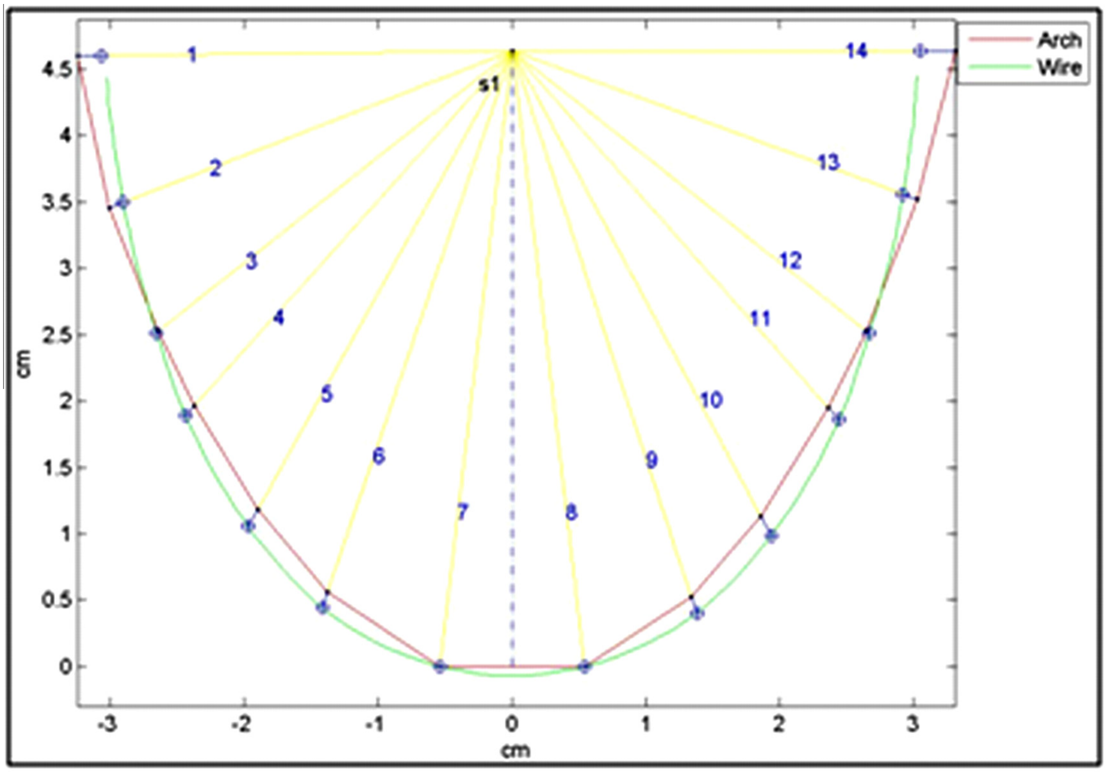

Figure 2 Wire superimposed on arch.

coefficients were used to compare results of the two digitization sets and to evaluate the reliability.

3. Results

Coefficients and significance values for correlations between the MAEs were calculated for 10 randomly selected cases. Good reproducibility was observed (reliability: 0.91–0.98). All cases (combined, male, and female cases) displayed significant differences in MAE among the wires ($P < 0.001$ by ANOVA, Table 1).

Table 2 displays the brands and MAEs for the best-fitting wires in each group. In the upper arch, the best fit and least error were obtained with RMO Ovoid (0.0896 cm) and Ormco Orthos Large (0.0899 cm) for male cases, but with 3 M Orthoform LA for female (0.0659 cm) and combined cases (0.0855 cm). In the lower arch, the best fit and least error were obtained with Ormco Orthos Large (0.0886 cm) for male cases, 3 M Orthoform LA (0.0695 cm) and RMO Normal (0.0714 cm) for female cases, and 3 M Orthoform LA (0.0905 cm), RMO Normal (0.0914 cm), Ormco Orthos Large (0.0924 cm), and Ormco Orthos Small (0.0947 cm) for combined cases. When the results of both arches were matched as pairs, the best-fitting wires were Ormco Orthos Large for male cases and 3 M Orthoform LA for female and combined cases.

4. Discussion

Correlation coefficients for MAEs between the original and redigitized data were 0.991 and 0.989 in the upper and lower arches, respectively ($P < 0.00$ for both arches). The paired t test did not detect differences in the MAEs between the original and the redigitized data ($P = 0.360$). Therefore, the method used can be considered sufficiently reliable.

When a preformed archwire is used in orthodontic treatment, the form of the treated dental arch is altered to match the form of the wire. NiTi wires are highly elastic preformed archwires that allow the introduction of larger cross-section wires and provide good efficiency during the early stage of orthodontic treatment (DeLa Cruz et al., 1995). Having archwires with forms that are harmonious with the normal dental arch form would be of great interest. Similar to studies by White (1978), Felton et al. (1987), Braun et al. (1999), and Camporesi et al. (2006), we compared preformed archwire forms to the dental arches of normal occlusion subjects. We studied 18 archwire designs from four popular orthodontic companies, including most designs and systems used in orthodontic practice and studied in prior investigations (Felton et al., 1987; Braun et al., 1999; White, 1978; Camporesi et al., 2006).

McLaughlin and Bennett (1999) illustrated the difference in arch forms produced from two sets of points of the same dental arch. The ‘‘research arch form’’ was generated by the buccal cusp tips of the posterior teeth, the cusp tips of the canines, and the midpoints of the incisal edges of the incisors. The ‘‘clinical arch form’’ was generated by the FA points. The two forms were different in shape and size. The research arch form was narrower and more constricted at the canine area, which gave a more tapered impression. Because the current study evaluated orthodontic archwires, the clinical arch form was chosen to represent the dental arches.

Differences in methodology between the present and previous studies make it difficult for us to compare the results. Archwires utilized in the present study were evaluated on each of the sample cases and not on a mean configuration arch of

Table 1 Anova test for upper and lower arches of male, female, and combined cases.

Cases		Sum of squares	df	Mean square	*F*	Sig.
Upper male	Between groups	0.637	17	0.037	22.474	.000
	Within groups	0.570	342	0.002		
	Total	1.207	359			
Upper female	Between groups	0.637	17	0.037	22.474	.000
	Within groups	0.570	342	0.002		
	Total	1.207	359			
Upper combined	Between groups	2.172	17	0.128	29.560	.000
	Within groups	3.034	702	0.004		
	Total	5.205	719			
Lower male	Between groups	1.047	17	0.062	9.128	.000
	Within groups	2.308	342	0.007		
	Total	3.356	359			
Lower female	Between groups	0.380	17	0.022	15.025	.000
	Within groups	0.509	342	0.001		
	Total	0.890	359			
Lower combined	Between groups	1.191	17	0.070	14.209	.000
	Within groups	3.462	702	0.005		
	Total	4.653	719			

$^{*}P < 0.001$.

Table 2 Best fitting wires for each sample group.

	Male cases		Female cases		Combined cases	
	Wire	Mean	Wire	Mean	Wire	Mean
Upper	RMO, Ovoid	.0896	3 M Orthoform LA	.0659	3 M Orthoform LA	.0855
	Ormco, Orthos arch, large	.0899				
Lower	Ormco Orthos arch, large	.0886	3 M Orthoform LA	.0695	3 M Orthoform LA	.0905
			RMO, Normal	.0714	RMO, Normal	.0914
					Ormco, Orthos arch, large	.0924
					Ormco, Orthos arch, small	.0947

the sample, as was done in studies by Braun et al. (1999) and Camporesi et al. (2006). Owing to the wide variation of normal arch forms and sizes, a single "ideal" arch form does not seem to exist. White (1978) adopted the same concept as us, but judged whether the fit of the archwire was good, moderately good, or poor by using a subjective visual examination of the superimposed wires on the mandibular arch of each case. In the present study, the upper and lower wires were evaluated quantitatively by measuring the difference between the dental arches and the wires in terms of the MAE.

Engel (1979) tested the fits of nine generated arch forms on a sample of upper and lower arches. Fit was considered acceptable if the error did not exceed 1 mm per tooth. However, Engel did not provide evidence on how this conclusion was reached. The results from the current study are restricted to identifying which wires fit the sample cases better than the other wires, regardless of how well the fit was. The findings do not suggest that any of the best-fitting wires will have an excellent fit on the entire sample, or that all cases should be treated with a single archwire form.

Chuck (1943) and Boone (1963) noted that although the Bonwill–Hawley archwire design is not suitable for use in most patients, it could serve as a template for construction of individualized arch forms. In the present study, the Bonwill–Hawley design (3 M Standard arch form) showed poor results, with the highest MAE in all sample groups. This finding means that the form of the treated arches will change substantially when NiTi wires are used, and that extensive wire customization will be needed when SS wires are used. On the other hand, the wires that produced the least amount of error would result in fewer changes in arch form during treatment and would need less customization when SS wires are used.

5. Conclusions

Using an archwire form that produces the lowest MAE would cause minimal change in the dental arch form when NiTi wires are used and would require less customization when SS wires are used.

Ethical statement

This study did not involve human subjects and was done in full accordance with the ethical principles of the College of

Dentistry Research Center of King Saud University, Riyadh Saudi Arabia.

Conflict of interest

The authors have no known conflicts of interest associated with the products used in this study that could have influenced its outcome.

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