AJO-DO

Objective vs subjective analyses of arch form and preformed archwire selection

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Introduction: Maintaining a patient's original arch form increases treatment stability. In this study, we assessed the agreement between subjective analyses of arch form and archwire selection by orthodontists and an objective method with Cast Analyzer Iranian X software (Khallaghane Mehr, Tehran, Iran). **Methods:** Thirty-six casts with normal occlusion were scanned with a laser. The software generated the best-fit curve using a fourth-degree polynomial equation to the clinical bracket points on the casts; then it selected the best preformed nickel-titanium archwire based on the root mean square calculation either objectively or semiobjectively. Three orthodontists selected the best-fit curve and archwire subjectively using the casts. To assess intraexaminer reliability, the same orthodontists reevaluated 10 casts after 2 weeks. To assess interexaminer reliability, the 3 orthodontists performed the analyses with the software and on the casts. Agreements were evaluated with the intraclass correlation coefficient and Dahlberg's formula. **Results:** The semiobjective method (visual selection of wire by orthodontists using the software) yielded the best results. The differences were clinically negligible between the objective (fully automated) and semiobjective methods (1.30 vs 1.36 mm). **Conclusions:** The objective method improved wire adaptation to the clinical bracket points. Agreement among orthodontists regarding wire selection will improve significantly when they are trained to use the software. (Am J Orthod Dentofacial Orthop 2016;149:543-54)

Andrews introduced the straight wire appliance in 1970 with the main goal of reducing chair time for the fabrication of archwires. It is now the most popular appliance used by orthodontists.[1] The archwire dictates the future arch form, and the teeth move within the created outline.[2] It seems that the range of selection in the current commercially available preformed orthodontic archwires does not appropriately cover diverse dental arch forms.[2]

Arch form classification is a subjective process occurring in the orthodontist's mind. Arch form has been described by geometric shapes such as catenary, parabolic, elliptical, and hyperbolic[3] and is usually categorized into 3 popular shapes—tapered, oval, and square—for simplicity in the clinical setting.[4] Arch form classification is usually done based on the clinical experience of the orthodontist or using preformed archwires from certain companies.[5]

Recently, there has been a growing tendency toward quantifying the data collected during the clinical examination and the dental cast analysis for both clinical and research purposes.[6] These efforts aim to provide objectivity for diagnostic procedures and achieve more realistic expected outcomes. Since the introduction of new computer-aided diagnostic systems, numerous studies have confirmed the validity and reliability of software programs for clinical decision making and treatment planning.[7-13] These studies have usually used parameters such as arch depth, arch width, and arch circumference for describing arch forms.[6] However, for a more precise description of arch form, we need to use mathematic models.[4,6] AlHarbi et al[6] acknowledged

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that the fourth-degree polynomial function offers the most reasonable model for dental arch description when there is a smooth curvature of the arch. Arai and Will[4] stated that the curve created by the fourth-order polynomial equation results in a smooth flexible curve that can be used as an archwire template for each patient.

Furthermore, different methods of fitting the curve of the preformed archwires to the patient's original arch form have been proposed in the literature.[2,5,14-16] Among these methods, the root mean square (RMS) is a standard mathematic value by which the similarity of 2 curves is evaluated (the more similar the 2 curves, the lower the value of the RMS). Therefore, with this value, the mean amount of difference between the patient's tooth and its corresponding point on the archwire can be assessed.

In other words, during the evolution of the straight wire technique, we attempted to achieve the best fit between the brackets and the straight wires inserted into them and the arch to make the fewest changes in the original arch form and ensure the stability of the treatment results. In this study, we evaluated the efficacy of a software program for more precise selection of preformed nickel-titanium archwires and arch form analysis for each patient. In addition, the role of clinicians in arch form analysis and archwire selection is discussed. We selected subjects with normal occlusion to prevent a possible confounding effect of the type of malocclusion on the orthodontists' clinical decision making.

For this purpose and to decrease the subjectivity in archwire selection, we developed a software program that allows the coordinates of the clinical bracket points (CBPs) to be uploaded by means of an imaging device (2 or 3 dimensional). Then a curve was fitted to the coordinates using a fourth-degree polynomial equation, and the best preformed archwire was selected by the smallest RMS (objective method). The aim of this study was to compare the developed objective method with the conventional method (subjective method routinely used by orthodontists) and the semiobjective method (archwire selection by orthodontists with the software). The role of orthodontists in clinical decision making in each of the 3 methods was also evaluated by calculating the intraobserver and interobserver reliability. In other words, we sought to assess whether the software was intelligent enough to act as do orthodontists in selecting the right archwire for each patient.

MATERIAL AND METHODS

This diagnostic study was conducted on 36 maxillary and mandibular dental casts (18 pairs) from subjects with normal occlusion. The sample size was calculated to be 36 considering a 0.6 expected agreement coefficient, a 95% confidence level ($\alpha = 0.05$), and a 0.16 estimation error. The number of samples was estimated based on the diagnostic aim of the study and for comparison of the methods. Each cast was considered as 1 sample because the wires are selected separately for the maxilla and mandible. The RMS was separately calculated for each sample. Therefore, 36 casts were used for the statistical analyses. The normal occlusion casts were selected from the archives of the Qazvin University of Medical Sciences in Qazvin, Iran, and belonged to adolescents (ages, 12 ± 1 years) with normal occlusion and no history of orthodontic treatment. The subjects had been followed for 4 years, and their final casts were used in this study.[17] The inclusion criteria consisted of acceptable facial proportions in clinical examinations, normal overjet and overbite, coincidence of the dental midline with the facial midline, maximum intercuspation, and Class I first molar and canine relationships. Carious interproximal surfaces, mild rotations, and crowding up to 2 mm were ignored. Normal occlusion casts were selected to minimize the confounding effect of treatment planning in the minds of the orthodontists on wire selection using the software.

This study had 2 main parts: arch form selection and archwire selection. First, the arch form curve was constructed. CBPs were demarcated according to the bracket placement guideline for preadjusted appliances using an orthodontic gauge (3M Unitek, Monrovia, Calif).[18] The CBP is the point where the bracket is attached to the tooth in the clinical setting. We digitized the location of these points and their coordinates using a 3-dimensional (3D) laser scanner (national patent number, 69383; Laser and Plasma Research Institute of Shahid Beheshti University, Tehran, Iran). The diagnostic value of this device has been previously assessed and confirmed.[13,19]

Pictorial (laser scanned) coordinates were converted to 3D spatial coordinates (x, y, z) using a computer. Spatial coordinates of CBPs were entered as x and y data into the software to draw a curve that proved to have the best compatibility with the arch form for each subject.[6] To adapt a curve to the CBPs, we omitted the z-dimension to construct a smooth curve indicating the subject's arch form. We used the Cast Analyzer Iranian X software (Khallaghane Mehr, Tehran, Iran), which uses the coordinates of bracket points to draw an arch form based on a fourth-degree polynomial equation ($ax^4 + bx^3 + cx^2 + dx + e$). This mathematic model has the best fit to a human arch form based on previous studies.[4,6] Cast Analyzer X software has a national patent (Iran 72897, version 1), and its reliability has been confirmed in previous studies.[20,21] Three-dimensional laser scanner and Cast Analyzer X software were collaborative projects of the Laser and Plasma Research Institute of Shahid Beheshti University and Shahid Beheshti University of Medical Sciences deputy of research and dentofacial research center in Tehran, Iran. Local patent numbers of the Cast Analyzer X (version 2) and the 3D laser scanner are 84356 and 69383, respectively.

The software enables automatic (objective) or manual (semiobjective) alterations in the angulation and direction of the curves to achieve the best adaptation of the curve to the respective points. The distance from each CBP to the drawn curve was measured, and the RMS value was calculated with the formula given to the software. This means that the distances from 14 CBPs were measured to the corresponding points along the x-axis on the polynomial curve fitted to them and squared. The mean of the squared distances was calculated, and the root of this mean indicated the amount of the RMS ($\text{RMS}=\sqrt{\sum x^2/n}$). The smaller the RMS value, the greater the adaptation of the arch to the CBPs. The objective and semiobjective methods in our study involved the use of Cast Analyzer X software.

For objective arch-form selection, the Cast Analyzer X software can automatically fit the best curve to 14 CBPs using a fourth-degree polynomial equation. In this procedure, the orthodontists had no influence on adapting the constructed curve to the CBPs; this task was performed solely by the software.

For semiobjective arch-form selection, the first orthodontist (M.N.), who was one of the software developers, changed the amounts of variables in the fourth-degree polynomial equation to achieve the smallest RMS value for the best-fit curve.

Archwire selection was the second step for selecting the best-fit archwire to the semiobjectively constructed curve for each dental cast. As mentioned earlier, the 3 orthodontists manipulated the polynomial equation variables to achieve the best-fit curve to the CBPs. Archwire selection was performed subjectively (visually), objectively (automatically), and semiobjectively.

For subjective archwire selection, the 3 orthodontists (M.N. and 2 others) fitted commercial nickel-titanium archwires to the dental casts manually to simulate what actually happens in the clinical setting (subjective method).

For the objective method, the software chose the best-fit wire for each arch based on the smallest RMS value among the scanned images of 4 pairs of prefabricated nickel-titanium archwires uploaded into the software in JPEG format (Figs 1 and 2). For selection of the best-fit archwire, the distances from 14 corresponding points on the polynomial curve along the x-axis to each archwire curve were the basis for the RMS calculation. The software enables insertion of the first-order deflection of the archwires when engaged in preadjusted brackets using the thickness of the preadjusted brackets (available from the manufacturing company or measured by any device); the thickness of the bracket is compensated for as such.[22] However, this value was not used in our study because it was the same for all 3 methods and therefore would not affect the results. The feature of adding the bracket thickness was designed in the software because of the variability of commercially available bracket types. Oda et al[2] reported that the bracket thicknesses were approximately 1.34 ± 0.16 mm for incisors, 0.75 ± 0.11 mm for canines, and 0.73 ± 0.08 mm for first molars in the mandibular arch. Selection of the best wire by the software was based on the RMS differences; the software prioritized wires as such by adapting 5 points to CBPs at the midline, canines, and molars.

In the semiobjective method, the 3 orthodontists visually selected the best wire for each polynomial curve by comparing the archwire shapes with the polynomial curve based on their clinical expertise without having the RMS values in the software. Figure 3 further clarifies this method. The first and second orthodontists had 15 to 17 years of clinical experience, and the third orthodontist had 5 years of clinical experience. After wire selection by the orthodontists, we needed to have a quantitative variable to assess the differences among the orthodontists and also between the software and each orthodontist. Therefore, selections were entered into the software, the RMS was calculated, and the means and standard deviations of these selections were estimated for each orthodontist. To assess the interobserver reliability, we chose 3 orthodontists based on qualitative studies so that the number of examiners would be odd.[21] We converted the type of wires selected by the orthodontists to their distances from the polynomial curve fitted to them by means of the RMS. By doing so, we changed the variable of wire selection to a mathematic calculation and a parametric variable.

In the final step, the best wire and curve selected by the orthodontists were compared with those selected by the software (as a reliable reference) based on mathematic calculations (ratio scale). The software curve and wire selections were considered as references because they were all measured by devices much more precise than human judgment. That is, the dimensions of the CBPs were identified with a laser scanner. Then a curve was fitted to them using a polynomial equation quantitatively calculated by means of the smallest RMS. The archwire fit to the polynomial curve was also based on the smallest RMS.

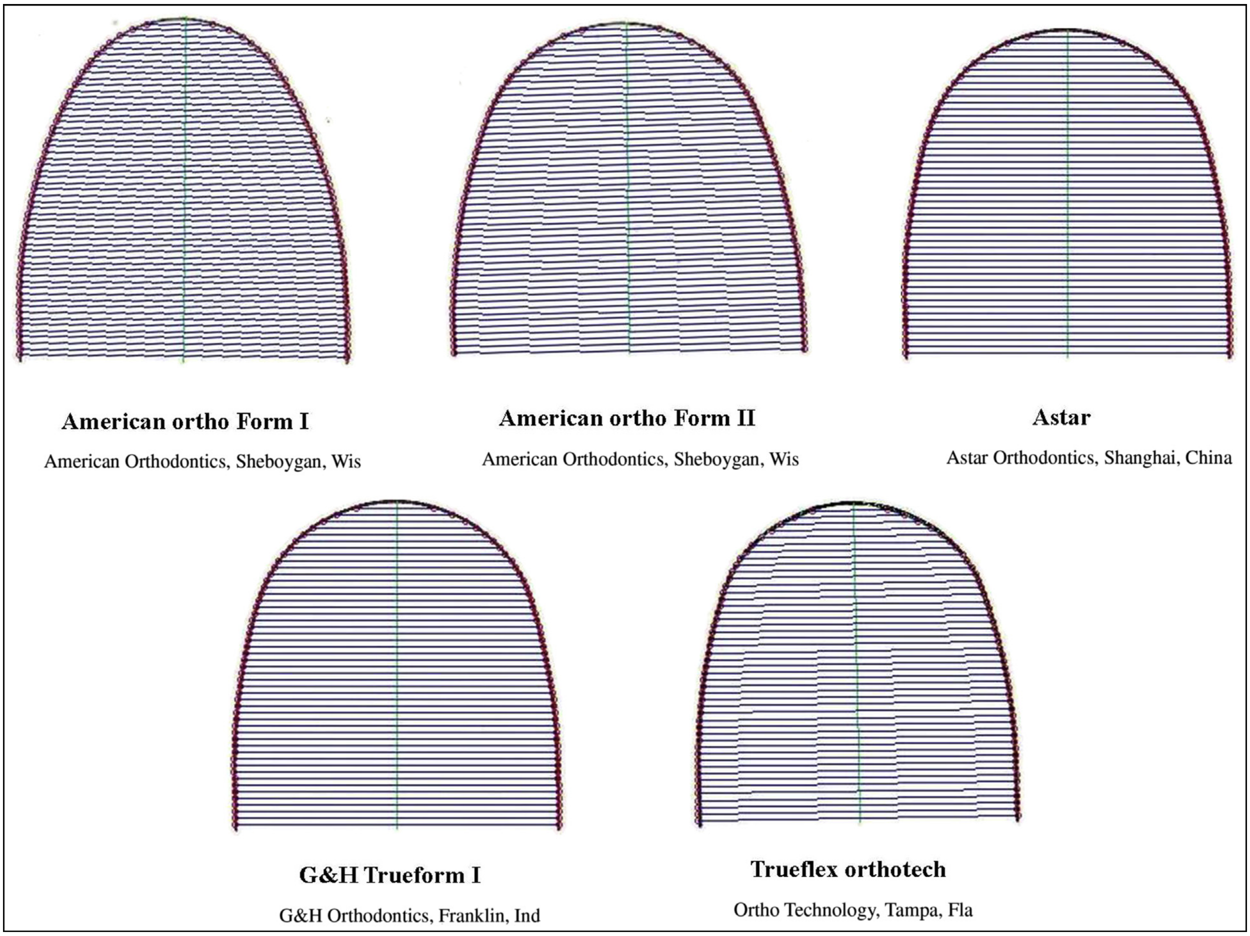

Fig 1. Shapes of 5 maxillary archwires.

To assess intraobserver reliability, the first orthodontist was asked to select the best curve and archwire for the second time for 10 casts after 2 weeks with all 3 methods.

Statistical analysis

For arch-form selection, the polynomial curve fit to the CBPs was assessed using the RMS value for each cast either by the software or after manipulation of the equation by the orthodontists to reach the smallest RMS. The means, standard deviations, and upper and lower boundaries of each RMS were calculated by the software for the 2 methods involving the software.

For archwire selection, as with the arch-form selection, the same statistics were used to describe the fit of the archwires selected by each orthodontist using the RMS values. The means, standard deviations, and upper and lower boundaries of the RMSs were recorded for all orthodontists for the 3 methods. The intraobserver reliability was calculated for the first orthodontist.

The intraclass correlation coefficient (ICC) was used to assess the agreement between the 2 methods, examiners (interobserver reliability), or time points (intraobserver reliability for the first orthodontist), and the values were compared. The differences in each comparison were calculated by Dahlberg's formula.[23] Although the ICC and Dahlberg's formula were proper indicators of reliability, we also assessed the significant difference between paired groups with paired *t* tests. Finally, the RMS values calculated by the 3 methods were compared using repeated measures analysis of variance with a 95% confidence interval. The agreement of wire type suggestions by the software and the orthodontists was assessed using the kappa statistic, ICC, Dahlberg's formula, and paired *t* tests.

RESULTS

For arch-form selection, the semiobjective method yielded a better fit by 0.05 $\pm$ 0.01 mm (lower RMS value) when arch-form adaptation was manipulated by the first

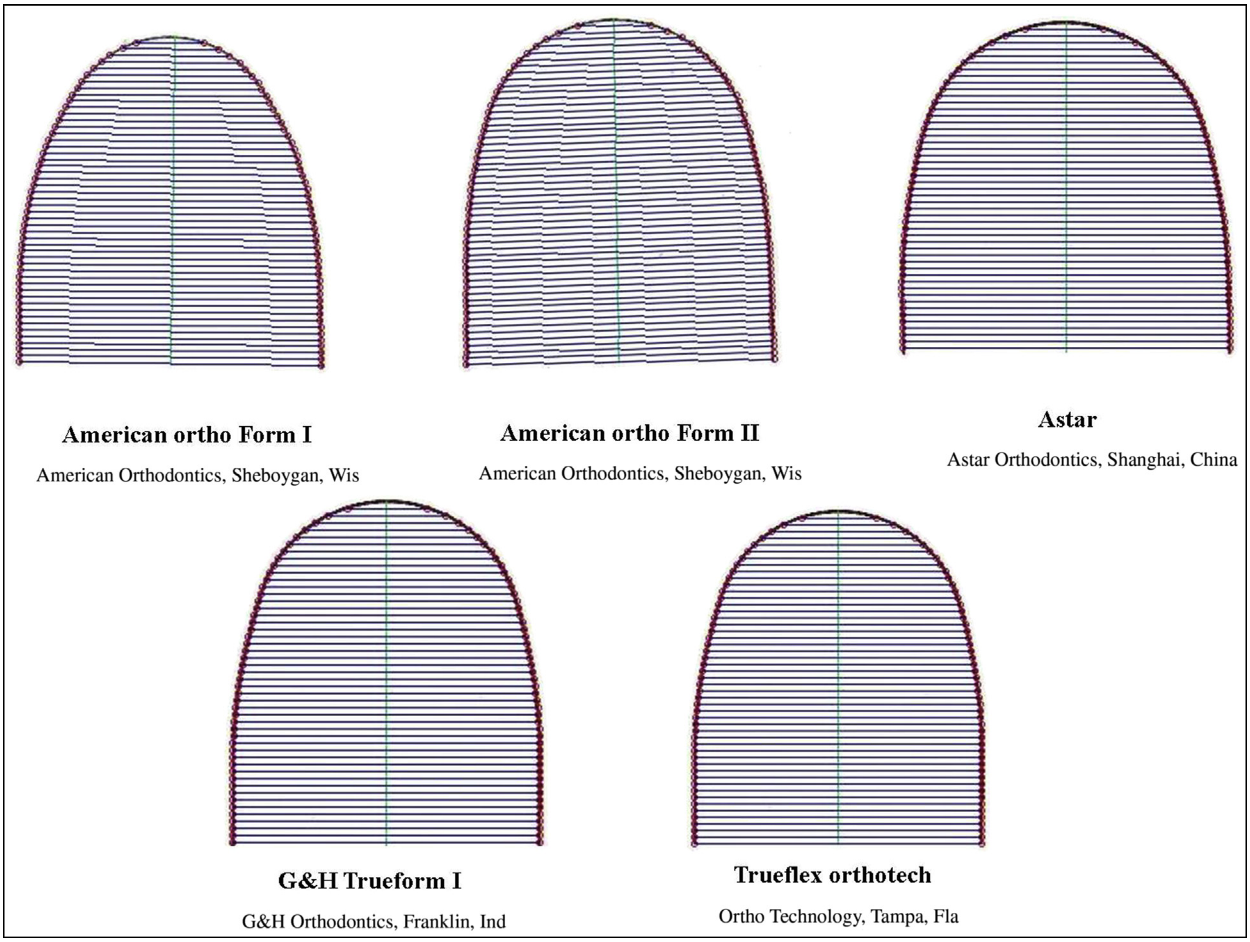

Fig 2. Shapes of 5 mandibular archwires.

orthodontist via changing the polynomial equation variables. The means, standard deviations, and upper and lower boundaries of the RMS values between the CBPs and the polynomial curve fitted to these points for the 2 methods involving the software are shown in Table I.

For archwire selection, the semiobjective method was found to be the best when the RMS values were compared. This means that the best fit was achieved when the orthodontists selected the wire in the software after constructing the polynomial curve. The means, standard deviations, and upper and lower boundaries of the RMS values calculated by the software for the 3 methods by each orthodontist are presented in Table II and Figure 4. The differences between the 2 methods involving the software were clinically negligible (1.30 compared with 1.36 mm for the first orthodontist). This indicates that the software was as valid as the orthodontist's judgment for archwire selection, based on the RMS values of subjects with normal occlusion.

Assessment of the interobserver reliability in the 3 methods showed a significant difference among the orthodontists, mainly caused by the second orthodontist's results. Table III demonstrates the interobserver reliability in the semiobjective, objective, and subjective methods among the 3 orthodontists. The lowest amount of agreement among the orthodontists was found in the subjective method (kappa coefficient, 0.33-0.45). By changing this value to a parametric value, the reliability increased. In the subjective method, the results of the second and third orthodontists were significantly different. The ICC was high (0.991) when the software was used in the objective method (for selection of the polynomial curve). This finding was probably attributed to the greater computer skills of the first and third orthodontists; a difference of only 0.055 mm was found between their selections. When the orthodontists manually manipulated the polynomial curve constructions by the software, the ICC increased by 0.996, and the difference decreased to 0.039 mm. This finding

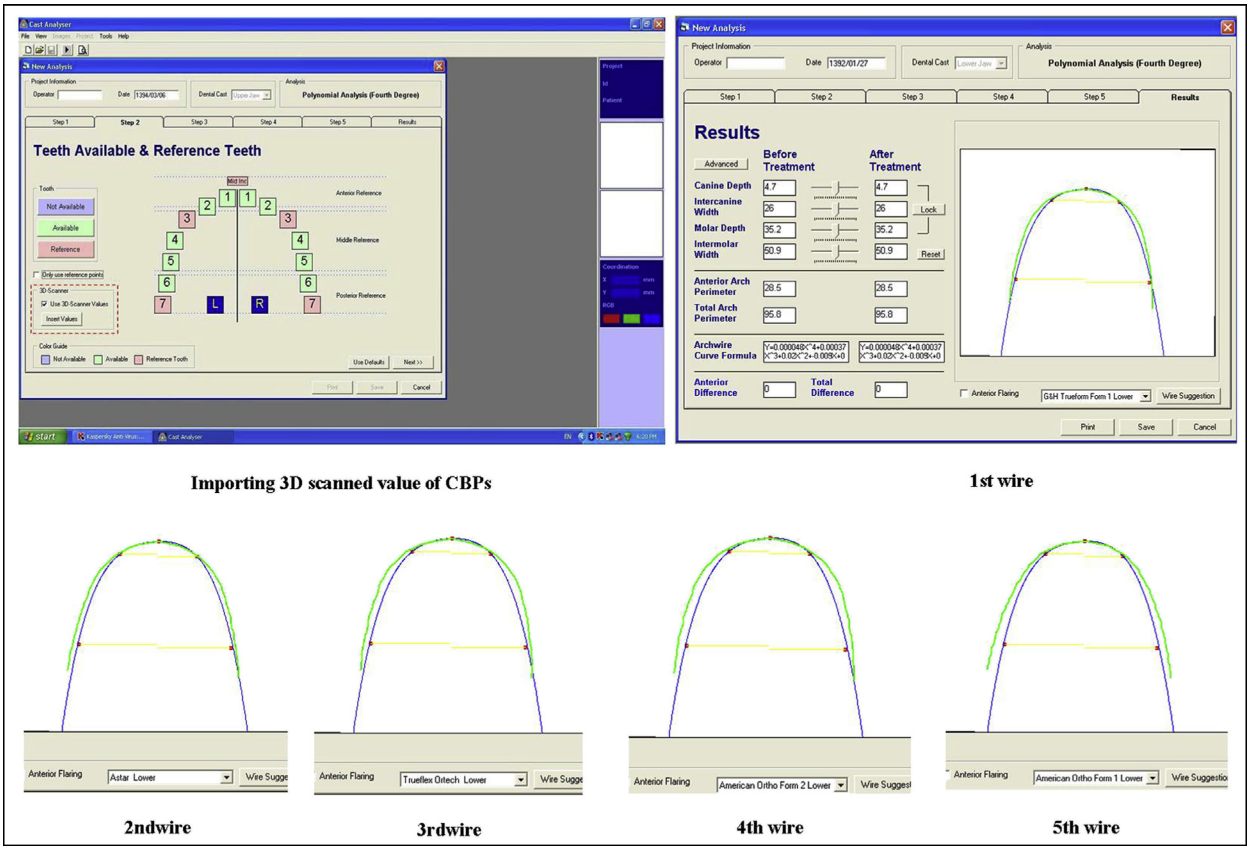

Fig 3. Screenshots of the step-by-step process of wire selection by the software.

Table I. Means, standard deviations, and ranges of RMS values (mm) calculated in the software between arches drawn by polynomial equation and CBPs in the different methods

Method	*Sample size*	*Mean*	*SD*	*Minimum*	*Maximum*
Objective	36	0.5056	0.16300	0.31	1.02
Semiobjective	36	0.4544	0.15413	0.29	0.99

indicates that if orthodontists are well trained on how to use all the features of the software, their choice of wire would almost be the same as other orthodontists for each patient; this is much different from what happens in the subjective method.

The reliability of the first orthodontist was excellent (>0.9) for each method (Table IV). When the first orthodontist selected the archwires, there were no significant differences in the RMS values calculated by the software for the 3 methods ($P = 0.065$). The post hoc results of pairwise comparisons of the methods at the 2 time points also indicated no significant differences. However, a significant difference was found between the subjective and semiobjective methods at days 1 and 10 for the first orthodontist. The discrepancies ranged between 0.018 and 0.041 mm.

The best-fit wires for subjects with normal occlusion were found to be Form II (American Orthodontics, Sheboygan, Wis) for the maxillary arch and Trueform I (G&H Orthodontics, Franklin, Ind) for the mandibular arch (among the 5 manufacturers). The overall agreement between the first wire selected by the software and by each orthodontist using the software or on the casts (subjective method) is shown in Table V. There were significant differences with regard to the second orthodontist's wire suggestions on the casts and with the software (objective and semiobjective methods). The performance of the second orthodontist with regard to wire selection improved using the software. Modification of the polynomial curve fit to the CBPs by the orthodontists semiobjectively resulted in an insignificant difference in agreement between the software and the orthodontists.

The agreement between the selections of each orthodontist subjectively and their performance using

Table II. Means, standard deviations, and ranges of RMS values calculated in the software between the wire suggestions from CBPs at different time intervals and methods by the 3 orthodontists

Method	*RMS (mm)*	*Sample size*	*Mean*	*SD*	*Minimum*	*Maximum*
Subjective	Orthodontist 1, day 1	36	1.4322	0.62273	0.69	3.80
	Orthodontist 1, day 10	36	1.4625	0.64334	0.66	3.80
	Orthodontist 2	36	1.7453	0.70910	0.60	3.73
	Orthodontist 3	36	1.5134	0.59719	0.60	3.73
Objective	Orthodontist 1, day 1	36	1.3600	0.58732	0.60	3.52
	Orthodontist 1, day 10	36	1.3681	0.58445	0.60	3.52
	Orthodontist 2	36	1.6667	0.81199	0.81	4.57
	Orthodontist 3	36	1.3483	0.58028	0.60	3.52
Semiobjective	Orthodontist 1, day 1	36	1.3044	0.59468	0.48	3.58
	Orthodontist 1, day 10	36	1.3128	0.59177	0.48	3.58
	Orthodontist 2	36	1.6244	0.93996	0.66	4.68
	Orthodontist 3	36	1.2933	0.59155	0.48	3.58

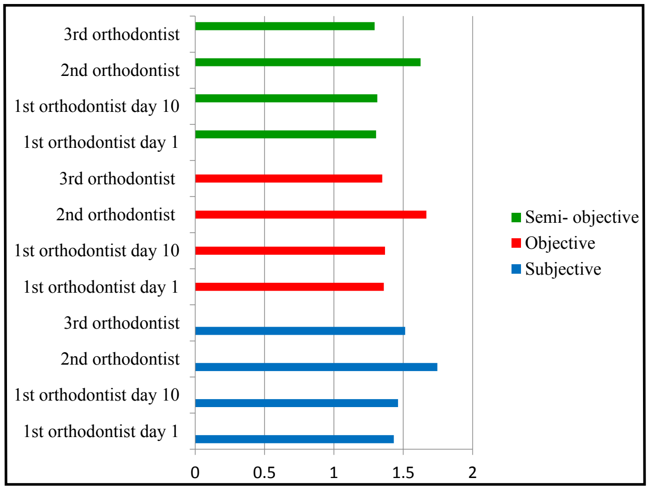

Fig 4. The RMS values for each orthodontist in the 3 methods after reverse engineering in the software indicating the x-axis distance in millimeters.

Table III. Interobserver reliability in the 3 methods among the 3 orthodontists

Method	*Orthodontists*	*Kappa*	*ICC*	*Dahlberg*	*P value*	*Significance*
Subjective	1 and 2	0.238	0.767	0.351186	0.005	S
	2 and 3	0.450	0.832	0.303747	0.012	S
	1, 2, and 3	0.333	0.850	0.241287	0.276	NS
Objective	1 and 2	0.603	0.498	0.540609	0.014	S
	2 and 3	0.687	0.493	0.543992	0.011	S
	1, 2, and 3	0.715	0.991	0.055327	0.378	NS
Semiobjective	1 and 2	0.603	0.508	0.588996	0.019	S
	2 and 3	0.687	0.508	0.591519	0.015	S
	1, 2, and 3	0.715	0.996	0.039511	0.238	NS

S, Significant difference; *NS*, no significant difference.

the software (objectively and semiobjectively) is presented in Table VI. The software improved the performance of the first and third orthodontists in terms of wire selections.

DISCUSSION

Proper archwire selection is an important step in diagnosis and treatment planning. It is determined based on the patient's dental arch form and the

Table IV. Intraobserver reliability of the first orthodontist in a time interval of 10 days in all 3 methods

	ICC	*Dahlberg*	P *value*	*Significance*
Subjective 1 and 10	0.940	0.018123	0.411	NS
Objective 1 and 10	0.995	0.039176	0.404	NS
Semiobjective 1 and 10	0.995	0.041667	0.391	NS
Subjective 1 and semiobjective 1	0.861	0.241005	0.022	S
Subjective 1 and objective 1	0.786	0.281055	0.282	NS
Semiobjective 1 and objective 1	0.914	0.174881	0.181	NS
Subjective 10 and semiobjective 10	0.809	0.286451	0.024	S
Subjective 10 and objective 10	0.764	0.301869	0.188	NS
Semiobjective 10 and objective 10	0.914	0.174805	0.182	NS

NS, No significant difference; *S*, significant difference.

Table V. Intraobserver and interobserver reliabilities and paired *t* test comparisons between the first wire selected by the software in 2 digitized ways and by each orthodontist in the software or on the casts (subjective)

Software suggestion in each digitized method	*Orthodontist*	*Kappa*	*ICC*	*Dahlberg*	P *value*	*Significance*
Subjective selection: software suggestion						
Objective	Orthodontist 1	0.532	0.840	0.240725	0.063	NS
	Orthodontist 2	0.091	0.617	0.42381	0.031	S
	Orthodontist 3	0.143	0.647	0.353604	0.865	NS
Semiobjective	Orthodontist 1	0.538	0.856	0.233372	0.733	NS
	Orthodontist 2	0.115	0.678	0.407189	0.010	S
	Orthodontist 3	0.141	0.667	0.358064	0.339	NS
Orthodontists' wire selections in the software: software suggestion						
Objective	Orthodontist 1	0.532	0.722	0.32794	0.023	S
	Orthodontist 2	0.636	0.528	0.488143	0.250	NS
	Orthodontist 3	0.500	0.709	0.335741	0.018	S
Semiobjective	Orthodontist 1	0.502	0.693	0.341652	0.181	NS
	Orthodontist 2	0.562	0.507	0.571784	0.118	NS
	Orthodontist 3	0.469	0.681	0.34861	0.148	NS

NS, No significant difference; *S*, significant difference.

Table VI. Kappa, intraclass correlation coefficient, Dahlberg, and paired *t* test of each orthodontist's selection between subjective and digitized methods in the software

Orthodontist's selection in the software vs subjective method	*Orthodontist*	*Kappa*	*ICC*	*Dahlberg*	P *value*	*Significance*
Objective	Orthodontist 1	0.091	0.860	0.324991	0.000	S
	Orthodontist 2	0.046	0.447	0.561866	0.843	NS
	Orthodontist 3	0.308	0.896	0.229086	0.000	S
Semiobjective	Orthodontist 1	0.091	0.831	0.328132	0.000	S
	Orthodontist 2	0.046	0.395	0.634684	0.560	NS
	Orthodontist 3	0.308	0.890	0.244023	0.000	S

S, Significant difference; *NS*, no significant difference.

treatment plan proposed for the patient. The orthodontist's conceptual understanding has a significant effect on each patient's treatment plan. Developing an objective method to confirm the orthodontist's decision will enhance treatment planning. This is especially true for nonformable nickel-titanium archwires. These wires may alter the patient's original arch form and compromise the stability of the results, especially in adults.[14]

In the clinical setting, orthodontists should select the best archwire among the available types in their office based on the patient's arch form and their clinical expertise. Classification of dental arch form is a subjective procedure. A trained clinician visually compares the position of canines to that of first or second molars in the arch and primarily classifies the arch form into tapered, oval, or square.[4] Although this subjective classification has sufficient validity and interexaminer and intraexaminer reliability compared with the standard templates,[3] it is unreliable for the intermediate ovoid arch form.[24] McLaughlin and Bennett[18] stated that intercanine width is the most important measurement required for subjective classification of arch form. Therefore, this variable should be measured manually with a caliper and is among the most practical quantitative methods for cast and arch-form analysis when using preformed archwires, especially for ovoid arch forms.[4] However, if the archwire is selected solely based on the intercanine width, up to 6 mm of discrepancy with the patient's arch form may result.[14]

As stated earlier, the simplest objective method is direct measurement of the 3 main determinants of arch form: arch perimeter, arch width, and arch length.[14] The measurements can be made directly on the dental cast using a caliper or on images of the dental cast with a 2-dimensional scanner (ie, digital images, photocopy, and holograms with reflex microscopy).[22] However, the literature shows that 2-dimensional methods have problems in completely registering anatomic landmarks such as contact points or curved structures such as tooth cusps, undercuts, or the curve of Spee. This can affect arch form construction and lead to improper treatment planning. Laser scanning, volumetric imaging, computed tomography, cone-beam computed tomography, structured light, and stereophotogrammetry are some available 3D imaging modalities. Laser scanning is the most popular method for dental cast imaging with high accuracy and reliability.[9,25-27] Therefore, we chose laser scanning as our method of choice.

Various methods have been introduced to find the best-fit archwire for an arch form.[2,5,14-16] In clinical practice, what usually happens is that the orthodontist simply compares them visually and chooses the one with the best fit based on his or her clinical expertise. Another method is to compare the intercanine and intermolar widths measured on the dental casts and the archwires.[14] Calculating the surface area of the arch and the archwire and comparing these 2 values using a software program is another acceptable method.[28] The RMS is one of the most reliable values for comparing the curves. With the RMS, the difference between the corresponding points on the arch and the archwire can be calculated. In our study, we needed a numeric measure to quantify our subjective data. Therefore, the RMS was chosen as the best compatible value. That means that when constructing the polynomial curve, the smallest differences between the CBPs and the polynomial curves fitted to them were considered. In addition, the RMS was used to find the archwires with the best fit. The RMS is a mathematic value to compare 2 distinct curves such as dental arches and archwires.[5,29] Because of recent advances in the use of technology in orthodontics, the curve fit to all CBPs can be assessed. In the orthodontic literature, arch forms have been usually compared by measurement of arch dimensions such as intercanine and intermolar widths or arch depth.[2,14]

All calculations in the software were made based on quantitative variables. We compared our newly introduced objective method with subjective (conventional) and semiobjective (common digital software) techniques. The subjective method is the routine method used by orthodontists. The preformed nickel-titanium archwire with the best fit is chosen by visually adjusting the wires on the cast to find the best-fit archwire to the patient's arch form. In the semiobjective method, the CBPs were marked on the cast using an orthodontic gauge; then the cast was scanned by a laser scanner. The 3 dimensions of each CBP were registered by the scanner, and the z-dimension was set to zero. A curve was fitted to these points using a mathematic fourth-degree polynomial equation in the software. The archwire form was also scanned and uploaded into the software. In the semiobjective method, the orthodontist visually chose the best-fit archwire to the polynomial curve fitted to the CBPs without having the RMS values. In the objective method, the coordinates of the CBPs were uploaded by means of a 3D imaging device. Polynomial curve fit to CBPs and archwire selections were based on the smallest RMS value calculated by the software. The proposed objective method seemed to be accurate for wire selection.

In our study, we used casts with normal occlusion to determine the accuracy and reliability of the methods. The reason for these casts was to minimize the effect of variations in treatment planning concepts on archwire selection among orthodontists. Intraobserver reliability was found to be high among the subjective, semiobjective, and objective methods. This indicates that our designed software can be used as an adjunct for archwire selection in orthodontic offices. The clinical implication of this issue was reflected in the second orthodontist's performance in our study. The interobserver reliability was high between the first and third orthodontists; however, the second orthodontist had low agreement with the others. This means that subjective comparisons are not as reliable as objective ones. Furthermore, making a mistake in mathematic calculations is quite possible despite high clinical expertise. Although the second orthodontist in our study had 17 years of clinical experience, a difference was noted between her selections and the choices made by the software in 50% of the cases. Use of new technology follows a learning curve. The more the orthodontists use the software, the more accurate the results will be. In both methods involving the software (objective and semiobjective), the agreement among orthodontists ranged from 0.60 to 0.71 (kappa statistic). The choices made by the second orthodontist had the lowest agreement with those of the 2 others. Kappa values ranged from 0.33 to 0.45 for the 3 orthodontists in the subjective method. However, the interobserver reliability ranged from 0.74 to 0.83 in this method. Changing the subjective to the objective method improved the level of agreement. In other words, using the RMS values, the objectivity was demonstrated via a parametric scale. This increases the accuracy of choices. In the semiobjective method, the first and the third orthodontists selected the same wires. However, the second orthodontist made different choices, perhaps as a result of her having a different concept with regard to wire selection or her different level of skills in using the software.

We sought to select the archwires with the best fit to the arch forms based on the smallest RMS values among 5 pairs of available preformed nickel-titanium archwires in Iran. Our results showed that in the best conditions, the curve constructed by the polynomial equation had a difference of 1.4 to 1.7 mm in the RMS value with the corresponding points on the orthodontic archwire. This would cause a difference of 3 to 3.5 mm in final tooth positions (on both sides). In the clinical setting, this amount of difference may not be important because it would be added to the premolar region of the curve. Based on previous studies, 2 to 3 mm of expansion in the premolar region would not invade the neutral zone[30] or compromise the long-term stability of treatment.[31] Furthermore, part of this difference will be compensated for by the thickness of the brackets.[2,32] Felton et al[33] compared arch forms with 17 commercially available (10 types) preformed archwires in 30 untreated patients, 30 Class I nonextraction patients, and 30 Class II nonextraction patients. In only 50% of them, the arch forms showed adequate adaptation with 2 specific archwires, and the remaining patients had a wide range of arch forms. The authors concluded that changing the arch form during treatment compromised the stability of the results. They added that relapse would eventually occur in 70% of the patients in the long term. We cannot expect all types of archwires to adapt to every arch form. Hence, it is necessary to make customized adjustments to improve the final stability of the arch form induced by archwires.

Oda et al[2] compared 20 preformed archwires with 30 mandibular dental arch forms in a Japanese population. They reported that the anteroposterior position of the archwire in the anterior segment was affected by 3 factors: bracket thickness, canine width, and first molar width. For this reason, we added the "bracket thickness selection" feature to our software. Using this feature, orthodontists can choose the bracket thickness from the drop-down menu. Oda et al also mentioned that the preformed archwires use the Roth prescription. This causes a similarity among the commercial wires. They stated that the Roth prescription was especially useful for extraction patients. In these patients, the molars usually have a mesial inward rotation, and greater torque must be incorporated into the brackets for more efficient space closure. Therefore, the archwire should be more constricted in the molar region to overcome this problem. Oda et al showed that the preformed archwires were narrower than the dental arch, especially in the molar region. Conversely, Braun et al[16] claimed that all 16 nickel-titanium archwires they examined were wider than the dental arch. Intercanine widths were 5.9 and 8.2 mm wider than those in mandibular and maxillary dental arches, respectively; these amounts for mandibular and maxillary intermolar distances were 0.8 and 2.6 mm, respectively. Similarly, Bhowmik et al[14] evaluated 30 rectangular nickel-titanium archwires in the dental casts of 20 male and 20 female patients. They found that the preformed archwires were wider by 6.2 to 7.1 mm in the maxillary region and by 5.3 to 6.6 mm in the mandibular intercanine region. These distances were 2.8 and 1.8 mm greater in the maxillary and mandibular intermolar regions, respectively. This controversy may be attributed to differences in ethnicity, sample selection, definition of reference points, and thickness of the brackets. In our study, we calculated the RMS. We did not specify our calculations to certain regions (eg, canine or molar). Our range of differences was between 0.48 and 4.68 mm. Some clinicians advocate that arch-form alterations by nickel-titanium archwires at the beginning of treatment can be corrected by subsequent use of customized stainless steel therapeutic archwires. This can increase total treatment time and also may cause a "round trip" for the teeth.[14,16]

In our study, which was based on subjects with normal occlusion, the agreement between the objective (with the software) and the subjective (manually by orthodontists) methods was 0.091 to 0.63; different values may be obtained for patients with malocclusion. Our results showed that the software assisted 2 orthodontists (with the skills for working with the software) in selecting wires with better fit to patients' arch forms. The semiobjective and the objective methods of wire selection in our study were based on 5 CBPs at the midlines, canines, and molars. Some modifications must be made to the polynomial curve fit to CBPs. Manipulation of the fourth-degree polynomial equation by orthodontists in our software to find the smallest RMS value would yield the best results. The software and the orthodontists' choices would be the same after this step. Our purpose in this study was to determine the magnitudes of differences caused by the available archwires if used as therapeutic archwires for patients with normal occlusion. Further studies are required to focus on patients with malocclusions to better compare the objective and subjective archwire selections.

CONCLUSIONS

The selection of archwires objectively improved the wire fit to CBPs. The agreement among orthodontists regarding wire selection will improve significantly when they are trained in using the software. For use in the clinical setting, the efficacy of the software must be evaluated in patients with malocclusion and normal occlusion in other ethnic groups.

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