Original Article

Mechanical Properties of Different Aesthetic Archwires

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ABSTRACT

Objectives: In response to patient demands for better aesthetics in orthodontics, manufacturers have developed different aesthetic wires and brackets. The aim of this study were to evaluate the mechanical properties of archwires. Thus, color properties and surface roughness of the different aesthetic archwires were analyzed.

Materials and Method: Seven brands of aesthetic archwires were evaluated for color and roughness measurements. The color measurement of each sample was performed using a spectrophotometer. A profilometer was used to measure surface roughness. For roughness, Ra (average roughness), Rq (root mean square roughness), and Rz (maximum peak to valley height) parameters were used. A Kruskal-Wallis test was used to compare intergroup differences. For pairwise comparisons, a Mann-Whitney U test was used.

Results: Intergroup comparisons revealed remarkable differences between groups for all parameters. The surface roughness and Commission Internationale de l'Eclairage L*a*b* color values were statistically different from each other for all intergroup comparisons ($p < .001$).

Conclusion: Having different color options for aesthetic wires gives clinicians an advantage in terms of the ability to choose archwires that are more harmonious with individual teeth in terms of bracket color and thus provide a more aesthetic appearance. (*Turkish J Orthod* 2014;27:85–89)

KEY WORDS: Aesthetics, Archwire, Color, Roughness

INTRODUCTION

There is a growing demand for better aesthetics during orthodontic treatment, and this demand has led to the enhancement of appliances that include good aesthetics and performance. For fixed orthodontic treatment, the introduction of aesthetic brackets partially solved the problem,[1] but most of archwires are still made of metals such as stainless steel. Coated metallic archwires are the only aesthetic archwires available for clinical usage.

Three types of esthetic archwires can be found: (1) OptiFlex (Ormco Corp, Calif, USA) archwires, which do not have desirable mechanical properties; (2) fiber-reinforced composite archwires, which are still at the laboratory level;[2] and (3) coated metallic archwires, which are the only aesthetic archwires currently available. Materials used in the coating process are plastic resin materials such as Teflon or epoxy resin.[3] The epoxy coating is manufactured using a depositary process that coats the base wire with an epoxy resin approximately 0.002 thick, so a powerful adhesion is achieved between the coating and the wire.[4]

In the literature, different opinions about coated archwires may be found. Coating creates a modified surface, which may alter corrosive properties, friction, and durability of the wires. A study about sliding properties and adherence of coating to the wires showed that the coating decreased friction between the wire and bracket.[5] The coated orthodontic wires have been found to be routinely damaged from mastication[6] and the coating has

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Table 1. Characteristics of the aesthetic 0.016″ × 0.022″ nickel titanium (NiTi) archwires used in the study

Manufacturer and Wire Name	Group	Coating Surface
Ortho Organizers, Sao Marcos, CA, USA, Coated Nitanium	OO	All surfaces
G&H, Greenwood, IN, USA, Orthoforce Ultraesthetic	GH	All surfaces
American Orthodontics, Sheboygan, WI, USA Everwhite Cosmetic	AO	All surfaces
SIA Orthodontics, Rocca d'Evandro, Italy, NiTi Coated Archwire	SIA	All surfaces
Hubit, Uiwang, Korea, Perfect Tooth Color Coated Archwire	HBT	All surfaces
Forestadent, Pforzheim, Germany, Biocosmetic Archwire	FRS	All surfaces
Eksen Medikal, Istanbul, Turkey, Coated Ultimate Archwire	EKS	All surfaces

been described as unstable.[7] Some authors have claimed that the color tends to change over time and that the coating breaks down during usage, exposing the underlying metal.[8]

Surface roughness of the archwire is an important factor in determining the effectiveness of archwire-guided tooth movement.[9] The surface topography affects the area of surface contact, influences corrosion behavior, and plays a role in color stability.[6] A previous study[10] reported that although frictional loss and rate of tooth movement are complex multifactorial processes, surface roughness might be related to the coefficient of friction of different archwires.

One of the major concerns for aesthetic archwires is color. Discoloration of aesthetic wires has internal and external causes. The type of coating material and its roughness also play a role in discoloration. The amount of discoloration can be altered by a number of factors, including oral hygiene, food dyes, and water absorption.[11]

Aesthetic archwires from different manufacturers are available in the market today, although research evaluating the mechanical properties of these wires is rare. It is also important to evaluate differences and advantages of these aesthetic archwires. Therefore, the aims of this study were to evaluate the color properties and investigate surface roughness of different aesthetic archwires.

MATERIALS AND METHODS

In this study, 7 brands of aesthetic archwires were evaluated (Table 1). The power analysis was established by G*Power version 3.0.10 (Franz Faul Universitat, Kiel, Germany) software. Based on the 1:1 ratio between groups, a sample size of 15 archwires per group would give more than 80% power to detect significant differences with a 0.35 effect size and at the α=.05 significance level. Sample preparations were performed using the same process as described in a similar study.[12]

Color Measurements

The color measurement of each sample was performed using the spectrophotometer VITA Easyshade Compact (VITA Zahnfabrik, Bad Sackingen, Germany). Before performing the measurements, the spectrophotometer was calibrated according to the manufacturer's instructions. The same operator performed all the measurements keeping the tip of the spectrophotometer perpendicular and flush to archwires surface. Five measurements of each of the 5 dry samples of each brand were performed to obtain the best result; this meant that 1 wire was measured 5 times and the average calculated. The average value of the measurements of each sample was recorded. Color changes were characterized using the Commission Internationale de l'Eclairage L*a*b* color space system (CIE L*a*b*),[3] which uses the following values: L* describes lightness with values from 0 (black) to 100 (white); a* describes color saturation from red to green on a scale of −60 to 60, where positive values indicate varying intensities of red; and b* describes color saturation from yellow to blue on a scale of −60 to 60, where positive values indicate varying intensities of yellow. Because visual color measurement is subjective, the color systems are quantitative systems with rectangular coordinates that allow objective measurement.

Surface Roughness Measurements

A profilometer (Mitutoyo Surftest, Tokyo, Japan) was used to measure surface roughness. When the profilometer is drawn across the surface by the drive unit, the tip follows the profile of the surface by moving vertically up and down. The diamond stylus of the profilometer has radius of 5 μm and a tip angle of 90° and traverses at a constant speed of 1 mm/second across the surface with a force of 6 mN. Three linear scans were performed per specimen surfaces. In view of the fact that roughness can be characterized using several different parameters, in this study we used Ra, Rq, and Rz parameters: Ra

Table 2. Descriptive statistics of the groups, including color and roughness parameters[a]

	L*			a*			b*		
Groups	Mean ± SD	Min–Max	Sig	Mean ± SD	Min–Max	Sig	Mean ± SD	Min–Max	Sig
OO	37.3 ± 1.82	33.5–39.4	A	2.86 ± 0.22	2.40–3.30	A	3.38 ± 0.67	2.00–4.20	A
GH	35.58 ± 1.22	33.4–36.9	B	1.66 ± 0.17	1.40–1.90	B	4.36 ± 0.57	3.50–5.40	B
AO	36.58 ± 0.77	35.5–37.5	A	0.50 ± 0.13	0.4–0.8	C	1.61 ± 0.37	1–2.10	C
SIA	35.10 ± 0.93	33.3–36.20	B	1.72 ± 1.19	1.0–6.0	D	3.46 ± 0.27	2.9–3.9	A
HBT	35.90 ± 1.47	33.2–38.9	B	0.52 ± 0.09	0.4–0.7	C	1.09 ± 0.19	0.9–1.5	D
FRS	36.55 ± 1.99	33.2–40.6	AB	0.50 ± 0.59	1.0–2.20	C	1.20 ± 0.33	1.0–2.0	D
EKS	31.4 ± 1.45	29.5–33.8	C	−0.97 ± 0.63	−2.10–0.20	E	0.84 ± 0.35	0.20–1.40	E

[a] Ra indicates average roughness; Rq, root mean square roughness; Rz (maximum peak to valley height); SD, standard deviation; Min, minimum; Max, maximum; Sig, significance letters for intergroup comparisons.

(average roughness) describes the overall surface roughness, Rq (root mean square roughness) describes the height distribution relative to mean line, and Rz (maximum peak to valley height) describes the average maximum peak to valley height of 5 consecutive sampling depths. Although Elayyan *et al.*[3] measured only 1 specimen in every group, in this study five measurements were performed for each specimen to obtain more ideal results. The mean value of 3 measurements on 1 specimen was used as the Ra, Rz, and Rq of that specimen.

Statistical Tests

All statistical analyses were performed with Statistical Package for Social Sciences (SPSS), version 15.0 software for Windows (SPSS Inc, Chicago, IL, USA). Arithmetic means and standard deviations were calculated for each measurement. The normality test of Kolmogorov-Smirnov with Lilliefors correction was applied to the data. The data were not normally distributed, and normality tests were also evaluated by histograms and box plot graphics. Thus, the statistical evaluation of the data was performed using nonparametric tests. The Kruskal-Wallis test was used to compare intergroup differences. For pairwise comparisons, the Mann-Whitney U test was used.

RESULTS

Intergroup comparisons revealed that there were remarkable differences between groups for all parameters (Table 2). The surface roughness and L*, a*, b* values were statistically different from each other for all intergroup comparisons ($p < 0.001$).

Surface roughness measurements with surface profilometry showed highly significant differences. For the Ra parameter, group OO had the highest value ($p < 0.05$). For the Rq parameter, group OO had the highest value and group FRS the lowest ($p < 0.001$). For the Rz value, Group GH had the highest value and Group FRS the lowest ($p < 0.05$). The mean surface roughness values are shown in Table 2.

Color measurements showed significantly different color and lightness properties in relation to parameters L*, a*, or b* (Table 2). For the L* and a* value, Group OO had the highest value and Group EKS the lowest For the b* value, Group GH had the highest value and Group EKS the lowest.

DISCUSSION

The aesthetic appearance of orthodontic appliances important to clinicians and patients. The color of aesthetic archwires must match that of natural teeth and aesthetic brackets. But the color of natural teeth changes according to the color investigation protocols used and by gender, race, and age.[14,15]

Measurements in the range of 1 unit are considered exact color matches because they can't be identified by independent researchers.[16] Because instrumental measurements affect the subjective interpretation of visual color evaluation, spectrophotometers are used instead of visual evaluation. Differences in color were characterized using the CIE L*a*b* system, which is currently one of the most popular and widely used systems of color investigation and is suited for the evaluation of small color changes.

In choosing an aesthetic archwire, the decisive factor must be individual tooth color. When the color

Table 2. Extended

Ra			Rz			Rq		
Mean ± SD	Min–Max	Sig	Mean ± SD	Min–Max	Sig	Mean ± SD	Min-Max	Sig
2.43 ± 0.16	2.16–2.69	A	2.86 ± 0.22	2.40–3.30	A	3.38 ± 0.67	2.00–4.20	A
1.35 ± 0.22	1.04–1.84	B	7.63 ± 2.10	5.12–12.31	B	1.74 ± 0.37	1.26–2.56	B
0.67 ± 0.21	0.41–1.23	C	3.08 ± 0.67	1.76–4.18	C	0.79 ± 0.25	0.79–0.85	C
0.31 ± 0.14	0.12–0.60	D	1.39 ± 0.35	0.84–2.17	D	0.37 ± 0.15	0.15–0.67	D
0.55 ± 0.50	0.42–0.62	CE	2.73 ± 0.28	2.20–3.12	A	0.61 ± 0.05	0.52–0.72	CE
0.31 ± 0.17	0.13–0.72	D	1.38 ± 0.50	0.91–2.99	D	0.38 ± 0.21	0.17–0.85	D
0.31 ± 0.24	0.12–0.75	DE	1.76 ± 1.12	0.77–3.84	D	0.39 ± 0.28	0.15–0.85	DE

of the aesthetic appliance matches the color of the natural teeth, this is considered the ideal aesthetic appearance.[17,18] In the results of this study, group OO had more lightness values, group GH had more yellowish values, and group OO had more reddish values than the other groups. This means that clinicians matching yellowish teeth should consider selecting group GH and those matching light-colored teeth should consider selecting group OO.

Surface roughness is an essential specification of an archwire. Besides its influences on sliding mechanics, surface roughness affects the aesthetics of dental products as well as corrosion behavior and biocompatibility. Surface roughness is an important factor in orthodontic treatment, and roughness influences friction. Rough surfaces may cause considerable friction because of the contact between interlocking peaks and valleys. [3] Frictional force is considered a major factor in orthodontic mechanotherapy, and research has shown that each force used to retract a tooth must overcome frictional forces.[19]

The surface roughness of orthodontic archwires may be measured using several methods, including laser spectroscopy, contact-surface profilometry, and atomic force microscopy. [2] One study reported that the results of surface roughness testing of different wires using these 3 techniques did not give different results, and the 3 methods generally correspond well.[9]

The parameters Ra, Rz, and Rq had statistically higher values, thus expressing greater surface roughness for the selected coated archwires. These results reveal the valleys and peaks of the surface raised. Our findings are in agreement with those of a similar study[20] that reported that there was an increase in surface roughness of wires after 4 weeks of use in the mouth.

Many studies have used Ra as the sole indicator of the surface texture, but this precludes a reliable registration of the surface texture because of two fundamental deficiencies:

1. Inability to determine the depth of the irregularity
2. The lack of information on the profile of the irregularity, such as peaks or valleys. Thus, surfaces showing identical Ra values can differ significantly in their roughness properties, and other roughness parameters (such as Rz and Rq) should be measured.[16]

Our study has some limitations. Color and roughness measurements were performed before clinical use, but measuring the values after clinical use and comparing them with the first values may give more satisfactory results.

CONCLUSION

Within the limitations of this study, conclusions are as follows:

1. All aesthetic archwires revealed different color and surface roughness properties.
2. Having different color options for aesthetic wires gives clinicians an advantage in terms of their ability to choose more harmonious archwires for individual teeth matching bracket color and providing a more aesthetic appearance.
3. The extreme variability of the surface roughness of orthodontic wires indicates that some manufacturers do not pay enough attention to the quality of their products.

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