A PROSPECTIVE COHORT STUDY ASSESSING THE APPEARANCE OF RETRIEVED ESTHETIC ORTHODONTIC ARCH WIRES

Journal:	*Orthodontics and Craniofacial Research*
Manuscript ID	OCR-2017-06-099-ORI.R1
Manuscript Type:	Original Article
Research Area:	Human study
Keywords (Please write 3 to 5 keywords according to Index Medicus):	archwire, esthetics, perceptions

Objectives

To investigate the appearance of three esthetic nickel titanium (NiTi) wires after 6 weeks of intra-oral cycling and to determine the association between objective and subjective measures of esthetics.

Setting and Sample Population

A prospective cohort study was undertaken involving participants undergoing upper fixed orthodontic appliance treatment with ceramic brackets.

Materials and Methods

Fifty participants were assigned to one of three groups of NiTi esthetic wires (American Orthodontics Ever White ™, Forestadent Biocosmetic ™ and GAC High Aesthetic ™), with wires retrieved after 6 weeks *in situ*. Participants completed a bespoke questionnaire exploring perceptions of wire esthetics. Objective measurement of coating loss was undertaken using a custom arch wire jig.

Results

American Orthodontics Ever White ™ had the greatest mean coating loss (50.7%) followed by Forestadent Biocosmetic ™ (6%), with GAC High Aesthetic ™ undergoing minimal loss (0.07%) ($P<0.001$). The majority of coating loss with the American Orthodontics Ever White ™ wires arose in the anterior region while Forestadent Biocosmetic ™ wires and GAC High Aesthetic ™ wires exhibited coating loss posteriorly ($P< 0.001$). These findings were reflected in the subjective assessment with a negative correlation found between coating loss and final VAS scores ($P< 0.001$).

Conclusions

Considerable esthetic variation between arch wires following 6 weeks of intraoral cycling was identified in this prospective cohort study. Intraoral cycling has a negative impact on participant perception of arch wire esthetics, and objective and subjective assessment of wire esthetics appears to be consistent.

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Introduction

The primacy of esthetic orthodontic goals is increasingly established with micro- and macro-esthetic ideals allied to enhanced facial and smile esthetics now a priority in orthodontics. [1] A corresponding emphasis on the appearance of the appliances themselves is also in vogue. [2] This likely relates both to heightened esthetic awareness generally but also to the popularity of adult orthodontics. [3,4] The latter has prompted a quest both to reduce treatment times and to minimize negative impacts of orthodontic appliances. [5]

The use of ceramic labial fixed appliance systems is popular among clinicians and patients. [2] However, coupling of ceramic appliances with metallic arch wires including uncoated Nickel-Titanium (NiTi) and stainless steel (SS) may dilute any esthetic advantage related to the ceramic, tooth-coloured attachments. [2, 6, 7] As such, esthetic alternatives have been developed including tooth-colored plastic and low reflectivity metals coatings, as well as non-metallic orthodontic arch wires.

Teflon (Polytetrafluorethylene) coatings have been used in orthodontic wires utilizing 'thermal spraying' with adsorption of finely-heated molten particles onto the metal surface. [8-11] Epoxy Resin is another synthetic coating applied to arch wires by an electrostatic process. This involves running an electric charge through the wire and applying the opposite charge to the resin. Atomized epoxy particles are then sprayed onto the arch wire and baked in a furnace. [9] In terms of low reflectivity metallic compounds, rhodium coatings offer a frosted appearance to maximize esthetics; however, these wires are not tooth-colored. [12] Despite the obvious potential esthetic value of these wires, some limitations have been reported, including significant discoloration[13], lower force delivery [14,15] as well as coating loss. [7,16]

There has been little objective or subjective esthetic evaluation of the appearance of esthetic orthodontic arch wires, particularly after intraoral cycling. Indeed, only one study has explored patient perceptions of esthetic orthodontic arch wires after intraoral use and this did not involve analysis of both subjective and objective measures. [16] Objective measures of outcome and treatment experience are not always mirrored in patient perceptions. [17] Moreover, self-perception of facial esthetics among adults has been shown to be negatively influenced by the presence of fixed appliances, particularly those with a metallic

appearance.[18] The aims of this research were therefore to assess the esthetic performance of three commercially available NiTi esthetic orthodontic wires in an objective and subjective manner after 6 weeks of intra-oral cycling. A secondary aim was to determine the association between patient-focused outcomes and objective measures of esthetic assessment.

Materials and Methods

Ethical approval for a prospective cohort study was obtained (QMERC2014/85). Based on previous research 15 participants per group were required to detect a minimum difference of 12mm (SD 10mm) in terms of the esthetic score based on a 100mm Visual Analogue Scale at the 0.05 level of statistical significance with a power of 90%.[19] To compensate for a dropout rate of at least 10%, the final number to be enrolled in the trial was 17 per group.

This study was undertaken in four private practices in London (U.K.) involving participants due to undergo fixed orthodontic appliance treatment with ceramic brackets in the maxillary arch. Participants were 18 years or older, in the permanent dentition and due to undergo treatment. Participants with cleft lip and palate and other craniofacial anomalies, and those unwilling to consent to inclusion in the study were excluded.

Fifty participants were assigned to one of three 0.014-inch NiTi esthetic wires (American Orthodontics Ever White ™, Forestadent Biocosmetic ™ and GAC High Aesthetic ™) based on existing operator preferences. These wires were retrieved after 6 weeks *in situ*. Following removal arch wires were washed under running water to remove any surface debris and wiped clean with Clinell ™ surface disinfectant wipes and placed in a sealable plastic bag.

Data Collection

Demographic information including gender and age was obtained for each participant. At the time of arch wire retrieval participants completed a questionnaire exploring perceptions of arch wire esthetics **(Figure 1).** A Visual Analogue Scale was used to determine perception of arch wire esthetics both pre-and post- treatment to provide quantifiable data of baseline impressions and changes in perception over time.[20]

Objective measurement of the magnitude, location and pattern of coating loss was undertaken using a custom fabricated arch wire jig. The jig was fabricated in the form of a 105 Euro Arch using dental stone. A paper rule with 0.5mm increments was secured and aligned to graph paper with 1mm increments. Once laminated this was mounted to the jig to

facilitate measurements based on a curved arch form. Each retrieved arch wire was placed into the jig and the ends secured with dental wax to permit visualization. Total coating loss was recorded as a percentage of the overall dimension. The anterior segment was also assessed and coating loss determined in the same manner by constructing a tangent from the midpoint of the arch form jig (representing the upper centerline) distally by 11mm. A perpendicular line was then drawn onto the jig from this point which measured 42mm across the arch form. This value was predetermined and based on the average inter-first premolar widths in Caucasian males of 36.7mm from the Michigan growth study [21]. An additional 5.3mm was added to account for bracket thickness and the difference between cusp tip and labial face. Any portion of arch wire anterior to this line was examined and measured 50mm in length around the arch form **(Figure 2)** allowing quantitative assessment of the extent of coating loss and color stability. Coating loss was scored from 1 to 6 as follows: 1= zero loss; 2= posterior loss only; 3= anterior loss only with one area only of less or equal to than 2mm; 4= anterior loss only with one area only of greater than 2mm; 5= anterior loss only with multiple areas of less than or equal to 2mm; 6= anterior loss only with multiple areas of greater than 2mm.

Data analysis involved descriptive statistics performed using software IBM® SPSS® Statistics version 23® [New York, USA]. A random sample of 20 wires was examined at a minimum of 1-week interval to assess intra-examiner reliability. [22] Kappa scores for color change and pattern of coating loss were 0.773 and 0.682, respectively, indicating good reliability. Assessment of coating loss and visual analog scale (VAS) scoring proved to be reproducible (ICC >0.96). Linear regression analysis was used to assess both VAS scores and coating loss for each wire type allowing for confounding factors including method of tooth brushing. Fishers exact test was used to assess categorical data in view of the small sample size. Both linear regression analysis and spearman's rank test was utilized to assess the relationship between subjective and objective data. The level of statistical significance was pre-specified at $P<0.05$.

Results

A total of 50 participants were recruited to this prospective cohort study. The majority (n=33) were female. The mean age of participants was 35.7 years (SD 12.7) with age ranging from 18 to 64 years. The average time wires were kept *in situ* was 44.3 (SD 11) days. In both American Orthodontics Ever White™ and Forestadent Biocosmetic™ groups, the majority of participants used electric tooth brushes at 59% and 80%, respectively.

American Orthodontics Ever White™ wires exhibited the greatest coating loss (49.47mm; SD= 23.22) followed by Forestadent Biocosmetic™ (6.40mm; SD= 14.82) with GAC High Aesthetic ™ having minimal loss (0.07mm; SD= 0.27) (**Table 1**). Linear regression analysis, confirmed a significant association between wire type and coating loss ($P < 0.001$) with both Forestadent BiocosmeticT™ (-47.63 units) and GAC High Aesthetic wire (-51.67 units) undergoing significantly less degradation than American Orthodontics Ever White™ wires. The R^2 was 0.72 indicating that a high percentage of the variance was explained by the type of wire (**Table 2**).

Coating loss measured in the anterior segment varied considerably between groups with American Orthodontics Ever White™ again exhibiting the highest level of coating loss with a mean of 18.67mm (SD 13.07) lost (37.3%). In the Forestadent Biocosmetic™ group, the mean coating loss was much lower at 1.33mm (SD 4.89) (2.67%) with GAC High Aesthetic™ group having no coating loss in the anterior segment. Linear regression analysis confirmed a significant association ($P<0.001$) between anterior coating loss and wire type with a significant proportion of loss attributable to wire type (R^2 0.59; **Table 2)**. These findings were confirmed with optical microscope (Olympus BX60 x 5) scanning (**Figure 2**).

In terms of patient perceptions of esthetics, at the time of initial wire placement the mean VAS score for the American Orthodontics Ever White™ arch wire was 75.33% (SD 15.35). However, at the time of wire removal the VAS score reduced by 30.64% to 44.69% (SD 18.22). Linear regression analysis confirmed a significant association with the VAS score and pattern of loss for all score except for score 3 ($p <0.001$). However only 2 observations occurred for this score. For every unit increase in total coating loss the VAS score decreases by 0.4% (**Table 2**).

Discussion

The intra-oral cycling period of 6 weeks was designed to represent that of a standard arch wire change. The exact duration *in situ* varied between participants: however, time intervals were relatively consistent with a mean time *in situ* for American Orthodontics Ever White™ of 46 (SD 13.08) days, which was 2 days and 4 days longer than with GAC High Aesthetic ™ and Forestadent Biocosmetic™, respectively. This may partially explain the increased coating loss associated with American Orthodontics Ever White ™ wires (50.7%) compared to the other wires; however, this time difference *in situ* was marginal. The bracket type and method of ligation was not standardized due to variation in individual operator practices,

although all operators used ceramic brackets and self-ligating brackets were not used. Bracket type does have the potential to influence both esthetics and coating loss; however, it was consistently observed that the less resistant wire (American Orthodontics, Ever White™) had coating loss both adjacent to the brackets and remotely. On the other hand, the rhodium-coated wire had minimal loss generally. As such, we feel that non-standardization of brackets did not have a significant bearing on the observed trends. Improved color stability with ceramic brackets compared to plastic brackets has been reported; however, clinically visible ceramic bracket staining and variation between types is recognized. [23] Differences in ceramic bracket design may therefore have influenced esthetic perceptions of the arch wires examined to some extent.

An initial aligning wire was examined in keeping with Elayyan *et al*. (2008) where an 0.016-inch NiTi was used. [7] During initial alignment, greater deflection of the arch wire is required to facilitate ligation, which may predispose to coating rupture. [24] Consequently, initial aligning wires may be at greater risk of delamination due to irregular tooth positioning and repeated deflections required for complete ligation. In contrast, Bradley *at el*. (2014) examined 0.016 x 0.022-inch NiTi wires when gross irregularities had likely been eliminated obviating the need for large deflections. [16] Similarly, Da Silva *et al*. (2013) used 20mm sections of esthetic rectangular 0.018 x 0.025-inch NiTi wires tied passively in the posterior region with stainless steel ligatures. [25] In the present study, coating loss was measured on the buccal surface as this is most apparent to participants contrasting with previous studies which used the occlusal surfaces. [7,16]

Considerable variation in coating loss was found in the present study mirroring the findings of Bradley *et al*. (2014) with American Orthodontics Ever White™ exhibiting 44.3% (SD 11.60) coating loss and 26.4% (SD 13.94) loss for the other coated arch wire assessed; [16] American Orthodontics Ever White™ underwent loss of 50.7% in the present study. Significant shedding of the esthetic coatings was also demonstrated in allied studies with coating loss ranging from 25% to 100%. [7,25] Coating loss in the anterior region was also accounted for in the present study as this has the most profound bearing on esthetic perception. [26, 27]

Interestingly, the metallic GAC High Aesthetic ™ was viewed most favorably both before and after intra-oral cycling despite. This contradicts previous studies which suggest that metallic components impact negatively on patient perception and that ceramic brackets with 'white wires' score more favorably than metal wires. [6,28] Bradley *et al.* (2014) used a Likert scale to determine perception of wire esthetics compared to tooth color and found that the majority of

participants were 'very pleased' with the American Orthodontics Ever White™. Despite this, metallic controls still scored favorably with the majority of participants 'pleased' with the appearance and no significant association noted between wire type and Likert scores. However, the previous study involved children and adolescents ranging from 9-20 years while adults only were considered in the present study. [16] Change in appliance perception with age is accepted, with younger children less concerned about metal display. [29] Despite this, these findings support the results from the present study that the metallic appearance of wires can be compatible with favorable perceptions.

There is an apparent tension between the esthetic motives prompting orthodontic treatment among adults and the temporary esthetic impairment associated with visible appliance components, with the latter risking a negative impact on social wellbeing, particularly in the initial stages of treatment. [4, 20, 31] This study highlights that after intra-oral cycling there is an increase in coating loss leading to greater metal show. It can therefore be inferred that the detrimental effects of intra-oral cycling on wire esthetics may have a negative effect on oral health-related quality of life and social wellbeing during treatment. Notwithstanding this, only one other study has considered patient opinion of wire esthetics [6]. This lack of patient-focused data is reflected in dental research more broadly. [32] It is therefore important that technological innovations undergo rigorous evaluation prior to marketing with detailed assessment both from a clinician and patient viewpoint.

Conclusions

Considerable esthetic variation between arch wires following 6 weeks of intraoral cycling was identified in this prospective cohort study. A clear relationship between objective and subjective assessments of esthetics after intra-oral cycling was identified.

Funding

All wires used in this study were freely provided by the manufacturers.

Conflict of Interest

The authors have no financial or other conflicts of interest to declare.

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Figure 1. Custom jig to allow evaluation of coating loss

Figure 2. Optical microscope (Olympus BX60 x 5) images of retrieved wires

A: American Orthodontics Ever White™

B: Forestadent Biocosmetic™

C: GAC High Aesthetic™

Table 1. Total coating loss

	Wire Type	Total coating loss (mm)	Percentage coating loss (%)	Total wire Length (mm)
American Orthodontics Ever White ™	N	18	18	18
	Mean	49.47	50.79	97.19
	SD	23.22	23.79	7.36
Forestadent Biocosmetic ™	N	15	15	15
	Mean	6.40	6.19	96.13
	SD	14.82	13.43	12.14
GAC High Aesthetic ™	N	14	14	14
	Mean	0.07	0.09	99.79
	SD	0.27	0.32	3.40

Table 2. Relationship between anterior coating loss and wire type, final VAS score and pattern of coating loss, and final VAS score and total amount of coating loss based on linear regression analysis.

	Anterior Coat loss	β-coefficient	95% CI		p-value
Wire type	American Orthodontics Ever White™	Reference	-		-
	Forestadent Biocosmetic™	-38.44	-50.85	-26.02	<0.001
	GAC High Aesthetic ™	-39.53	-52.04	-27.01	<0.001
Brush type	Manual	2.21	-9.09	13.51	0.695
	Electric	Reference	-		-
	Final VAS score				
Pattern of Loss	1	Reference	**-**		**-**
	2	-17.62	-33.43	-1.80	0.03
	3	-11.73	-40.89	17.43	0.42
	5	-22.56	-39.52	-5.60	0.01
	6	-31.45	-46.83	-16.08	0.00
	Final VAS score				
	Total Coating Loss	-0.40	-0.60	-0.20	0.00
	Anterior Coating Loss	-0.42	-0.66	-0.17	0.0001

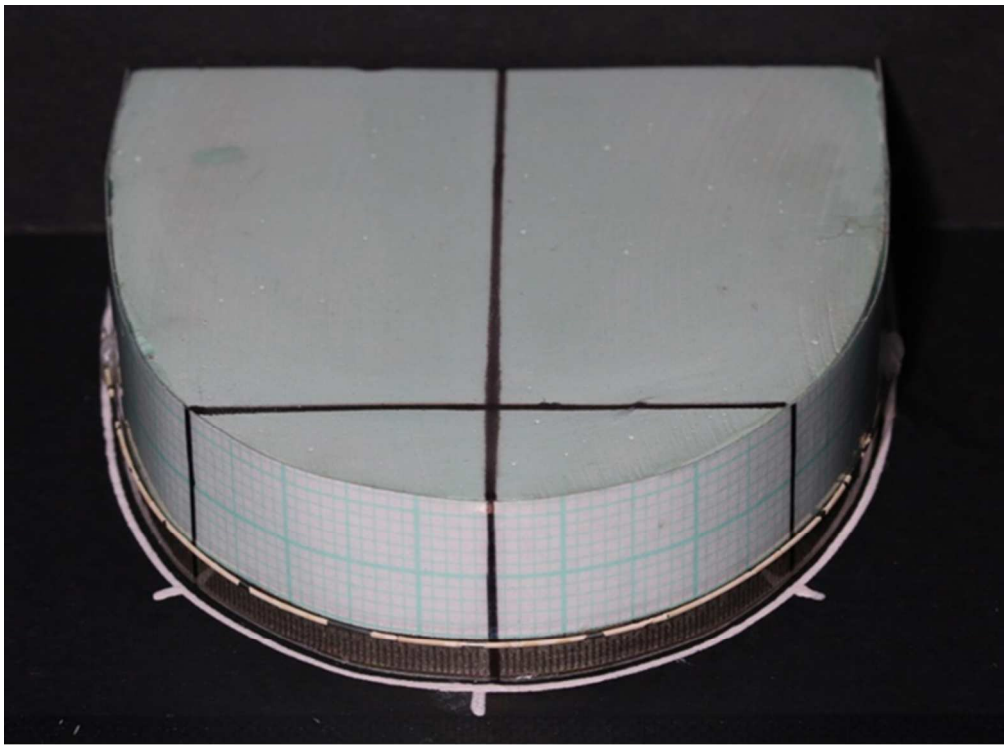

Figure 1. Custom jig to allow evaluation of coating loss ‼ ┼

57x42mm (300 x 300 DPI)

Figure 2. Optical microscope (Olympus BX60 x 5) images of retrieved wires ‼ ┼ A: American Orthodontics Ever WhiteTM‼ ┼ ‼ ┼

325x232mm (300 x 300 DPI)

Figure 2B: Forestadent BiocosmeticTM ‼ ┼

133x95mm (300 x 300 DPI)

Figure 2C: GAC High AestheticTM ‼ ┼

84x60mm (300 x 300 DPI)