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Research paper

Changes in dental and basal archforms with preformed and customized archwires during orthodontic treatment

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ABSTRACT

Objectives: To evaluate changes to the dental and dentoalveolar (WALA Ridge) arch widths with preformed and customized archwires during orthodontic treatment.
Methods: 20 patients treated with preformed archwires and 20 treated with customized archwires were recruited. Pre-treatment (T1) and post-treatment (T2) mandibular casts were used to determine the changes in dental and dentoalveolar arch width measured at the canine, premolar and molar areas. Ratios of transverse dental to dentoalveolar movements were also calculated. Results were compared to an untreated control group with mandibular casts taken at two comparable time points. Data were analyzed using ANOVA and *t*-test.
Results: Significant changes in dental and dentoalveolar arch width were found with the preformed archwire group when compared to the control ($p < 0.05$). However, no significant changes in dental and dentoalveolar arch width were found with the customized archwire group compared to the control. Significant correlations were found between the dental and dentoalveolar arch widths. However, the ratios of dental to dentoalveolar transverse change differed between the groups and indicated that the types of movements were contrasting between the preformed and custom arch forms as each expanded the dental arches.
Conclusions: The WALA Ridge is a stable landmark when archwires are customized or shaped to the WALA Ridge. Changes in the WALA Ridge are expected when preformed archwires are used which do not conform to the patient's dentoalveolar arch width defined by the WALA Ridge. This is probably accounted for by the different types of tipping combined with extrusion that both methods employ.

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1. Introduction

Researchers and clinicians have attempted to determine and classify appropriate dental arch forms. With the advent of the pre-adjusted straight wire appliance, attempts have been made to design and commercialize archwires with ideal arch form [1–6]. Classification of arch forms has involved various geometric and complex mathematical formulas [2,7–10]. Manipulation of the dental arch form has suggested impact on the stability [11–22] and the periodontium [23–30]. To minimize orthodontic relapse, several methods have been suggested, including maintenance of the mandibular incisors in their pre-treatment position and preservation of the original arch form [31]. Several methods have been proposed to design unique arch forms for individual patients [5,32]. Many protocols shape wires to the arch form of the pre-treatment dentition [5,13,17,33]. However, this is often not transferred in clinical practice [34]. In addition, there are claims that expansive buccal tooth movement can occur without tipping if extremely light forces are employed during treatment [6]. To date, there is no consensus within the profession on a tangible landmark to use in shaping arch wires.

In 2000, Andrews proposed the WALA Ridge as a defendable landmark to serve as a template for shaping mandibular arch wires [35]. He defined the WALA Ridge as a band of soft tissue immediately coronal to the mucogingival junction of the mandible and being at or near the level of the center of rotation of the teeth. A recent study by Ronay et al. [36] shed evidenced based light on this structure and concluded that the WALA Ridge can be useful in predetermining a customized dental arch form. They found that arch forms derived from either the crowns' facial axis (FA) points or the WALA Ridge are individual and cannot be defined by one generalized shape, thus supporting the need for customizing arch wires. An ideal landmark is one to which the relationship of optimally positioned teeth can be measured to. To be reliable, a landmark must be stable from pre-treatment to post-treatment.

The objective of this study was to determine the changes in dental and dentoalveolar arch widths in patients treated with preformed archwires and those treated with archwires customized using the WALA Ridge as a pre-treatment landmark. The null hypothesis was no significant changes occur in dental and dentoalveolar arch widths using either preformed or customized archwires during orthodontic treatment.

2. Methods and materials

2.1. *Control group*

Mandibular casts of 10 non-orthodontically treated patients were obtained from The Ohio State University Department of Orthodontics, Columbus, OH. A control group of untreated subjects was included to account for changes in basal and dental archforms that were due to growth. The inclusion criteria for selecting these subjects were: no previous orthodontic treatment, a minimum of 2 years between the acquisition of the initial and follow-up (T1 and T2) mandibular dental casts and the presence of permanent teeth from second molar to second molar. Matching the experimental group, subjects had Class I occlusions and, no anteroposterior discrepancy. The average age of the final sample was 13.8 ± 2.5 years with equal male and female subjects.

2.2. *Experimental groups*

Mandibular casts of 20 patients, matched in age and sex with the control group, treated with preformed archwires or customized archwires were obtained from the private practices of two of the investigators. In order to standardize the treatment of the two operators, both were board certified orthodontist with a minimum of 25 years of experience. In both groups, all permanent teeth including second molars were bonded or banded in the upper and lower arches. The first group treated with Damon (Ormco Company, Glendora, California) preformed archwires (Fig. 1) was obtained from the private practice of one investigator (T.D.). A straight wire appliance with a .022 × .28 slot bracket and Damon prescription was used. The mandibular archwire sequence used was .014″ CuNiTi, .016″ × .015″ CuNiTi and .016″ × .025″ SS and the practitioner did not fill the slot with the final archwires. The second group using archwires (G&H Wire Company, Franklin, Indiana) customized to the WALA Ridge (Fig. 2) was obtained from the private practice of another investigator (T.T.). A straight wire appliance with a .022 × .028 slot bracket and standard Andrews prescription was used. The mandibular archwire sequence used was .012″ NiTi, .018″ NiTi, .018″ SS and .018″ × .025″ SS and the practitioner did not fill the slot with the final archwires. In this group, the WALA Ridge was used as a template to fabricate the final archwires. The operator formed the mandibular archwires to the shape of the WALA Ridge with consideration given to the norms for the distance in mm of the FA points of the clinical crowns to the WALA Ridge and the prominence set by the bracket slot. The final archwires were therefore shaped slightly away from the WALA Ridge in the incisal area and slightly inside the WALA Ridge in the molar area. In addition, the inclusion criteria for selecting these subjects included the presence of

Fig. 1 – Preformed archwire used in one of the experimental group.

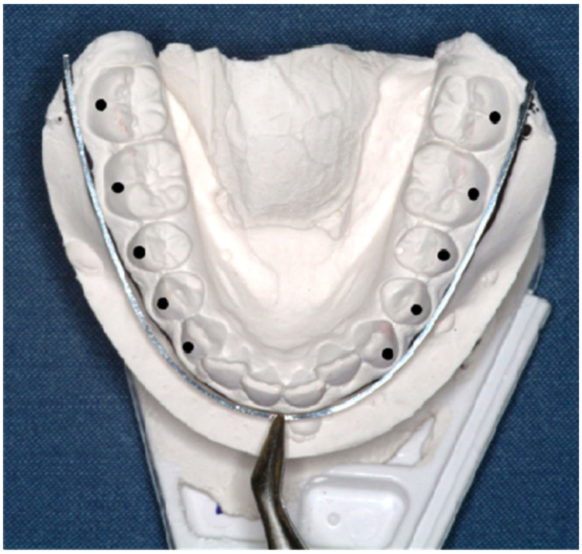

Fig. 2 – Archwire customized to the WALA Ridge used in one of the experimental group.

Fig. 3 – Measurement of dental arch width from FA point of a tooth to the contralateral tooth.

all permanent teeth from second molar to second molar, a Class I occlusion with no anteroposterior discrepancy, and a non-extraction treatment plan. The average age of the preformed archwire group was 13.2 ± 2.1 years and the customized archwire group was 12.8 ± 2.3 years with equal male and female subjects.

2.3. *Measurement of changes in dental arch width*

The FA points of the canines, first premolars, second premolars, first molars and second molars were marked on all the pre- and post-treatment mandibular casts using the method described by Andrews [37]. The transverse distances between the FA points of the corresponding contralateral teeth were measured using a digital caliper (General Tools and Instruments, New York, New York). The dental arch width measurements (D) were recorded to the one thousandth of a millimeter in order to establish a baseline dental arch width prior to treatment (Fig. 3).

2.4. *Measurements of changes in dentoalveolar arch width at the WALA Ridge*

The WALA Ridge on the pre- and post-treatment mandibular casts were outlined from second molar to second molar with a 2H pencil. The facial axes of the clinical crowns (FACC) were marked and the pencil line extended gingivally until it intersected with the already marked WALA Ridge. The dentoalveolar arch width (DA) or the transverse distance at the intersection of the WALA Ridge and the FACC was then measured to the contralateral side at each tooth within one thousandth of a millimeter (Fig. 4). If the pre-treatment casts had any significant rotation mesially or distally, a corrected FA point and FACC mark were placed in what would be the anticipated position following treatment.

2.5. *Statistical analysis*

A post hoc power analysis was performed because of the small sample size in the experimental group (20 in each group). To detect a difference of one mm in dentoalveolar pre-treatment arch width for the preformed and the customized archwire groups, a two sided test at a level of significance yielded a 0.05 of 0.87, a sample of 20 per group was adequate. An analysis of variance (ANOVA) was used to compare each of the three groups with respect to mean changes from T1 to T2. A Tukey–Kramer multiple comparison procedure was used to compare the mean difference for all pairs of groups. The ANOVA was again repeated to determine if there were significance differences from T1 to T2 between each experimental group and the control. Correlation coefficients between the dental and dentoalveolar arch widths for the preformed and

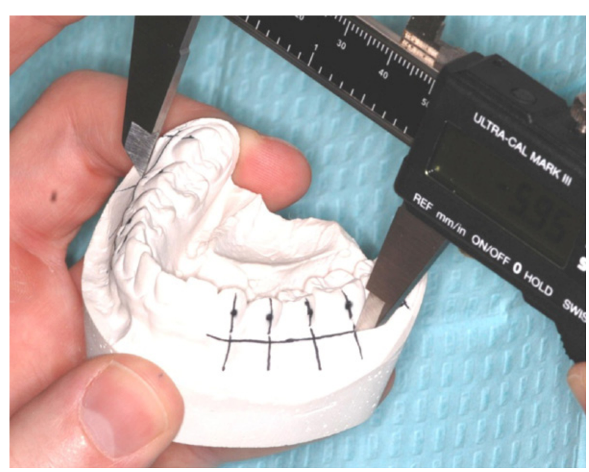

Fig. 4 – Measurement of dentoalveolar arch width. The facial axes of the clinical crowns (FACC) were marked and the pencil line extended gingivally until it intersected with the already marked WALA Ridge. The dentoalveolar arch width (DA) or the transverse distance at the intersection of the WALA Ridge and the FACC was then measured to the contralateral side at each tooth.

Table 1 – Correlation coefficients between the first and second measurements for the dental (D) and dentoalveolar (DA) arch widths for the second molars (7-7), first molars (6-6), second premolars (5-5), first premolars (4-4) and canines (3-3).

Measurement dimension	Correlation coefficients
7-7D	0.93
6-6D	0.94
5-5D	0.91
4-4D	0.91
3-3D	0.76
7-7DA	0.95
6-6DA	0.99
5-5DA	0.97
4-4DA	0.89
3-3DA	0.95

customized archwire groups were computed and tested for significance. Ratios were calculated for each tooth's paired transverse distance — dental distance change:dentoalveolar distance change. This demonstrated the type of movement obtained by comparing the dental crown movement and the purported center of rotation movement.

3. Results

Intra-rater reliability was tested by randomly selecting 10 patients and re-measuring the models at least 2 weeks from the time of the original measurements. Correlation coefficients between the first and second measurements were computed for the dental and dentoalveolar arch widths (Table 1). In general most of the measurements were reliable with coefficients greater than 0.90.

Table 2 summarizes the dental and dentoalveolar arch width changes (T1 to T2) at all measurement points for the control and both treatment groups. Significant differences in dental arch width were found for all measurements in the preformed archwire group, and for all measurements in the customized archwire group except the canine measurement. On the other hand, significant differences in dentoalveolar arch width were found for all measurements in the preformed archwire group except the canine measurement, but no significant differences were found in the customized archwire group with the exception of the second molar measurement.

Table 3 shows the correlation between the change in dental arch width and dentoalveolar arch width in the treatment groups. Significant correlations were found for all measurements in the preformed archwire group. Significant correlations were found only for the second molar, first molar and the second premolar measurements in the customized archwire group.

Table 4 compared the dental dimension to dentoalveolar dimension changes. Differences in ratios were found for the two types of archwires as the arches changed shape.

4. Discussion

In this study, the shape of the arch wire and the bracket system employed for orthodontic treatment determined the arch form at the completion of fixed orthodontic therapy. Significant increase in dental arch width was found in both the preformed and customized archwire groups after treatment (Table 1). However, compared to the control group, significant increase was found only in the preformed archwire group (Table 2). This is likely due to the greater transverse and poor resemblance of the preformed archwires to the pre-treatment arch form especially in the posterior teeth. In contrast, the customized arch wires were contoured to the WALA Ridge with less increase in the dental arch width.

Significant increases were found in the dentoalveolar arch width for all measurements in the preformed archwire group,

Table 2 – Comparison of dental (D) and dentoalveolar (DA) arch width changes for each treatment group and control, and between the treatment and control groups for the second molars (7-7), first molars (6-6), second premolars (5-5), first premolars (4-4) and canines (3-3).

Dimension	Control difference (T2 − T1)		Preformed differences (T2 − T1)		Customized differences (T2 − T1)		Preformed vs. control		Customized vs. control		Preformed vs. customized	
	Mean SD (mm)	Signif	Mean SD (mm)	Signif	Mean SD (mm)	Signif	Diff (mm)	Signif	Diff (mm)	Signif	Diff (mm)	Signif
7-7D	0.14 0.76	NS	2.03 1.67	***	1.38 1.29	***	1.89	*	1.24	NS	0.65	NS
6-6D	0.32 0.46	NS	1.76 1.60	***	1.23 1.58	***	1.44	*	0.91	NS	0.53	NS
5-5D	0.41 0.72	NS	1.78 1.36	***	1.16 1.36	***	1.37	*	0.75	NS	0.62	NS
4-4D	0.21 0.50	NS	1.76 1.53	***	0.90 1.34	**	1.55	*	0.69	NS	0.86	NS
3-3D	0.27 0.29	NS	1.14 1.77	**	0.47 1.61	NS	0.87	NS	0.2	NS	0.67	NS
7-7DA	−0.01 0.48	NS	0.89 1.25	***	0.44 0.66	*	0.9	*	0.45	NS	0.45	*
6-6DA	0.06 0.62	NS	1.23 0.07	***	0.07 1.14	NS	1.14	*	0.01	NS	1.13	***
5-5DA	−0.14 0.75	NS	1.79 1.11	***	0 0.37	NS	1.93	*	0.14	NS	1.79	***
4-4DA	−0.05 0.46	NS	1.80 1.38	***	0.49 2.27	NS	1.85	*	0.54	NS	1.31	*
3-3DA	−0.09 0.66	NS	0.85 1.48	***	−0.26 0.56	NS	0.94	*	−0.17	NS	1.11	**

NS = non-significant.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 3 – Correlation (*R*) of net treatment change dental (D) and dentoalveolar (DA) arch width for the preformed and customized archwire groups for the second molars (7-7), first molars (6-6), second premolars (5-5), first premolars (4-4) and canines (3-3).

Dimension	Preformed archwire group			Customized archwire group		
	R value	*p* value	Sig.	*R* value	*p* value	Sig.
7-7D/7-7DA	0.55	0.01	*	0.62	0.003	**
6-6D/6-6DA	0.65	0.002	**	0.69	0.0008	***
5-5D/5-5DA	0.61	0.004	**	0.51	0.02	*
4-4D/4-4DA	0.75	0.0001	***	0.13	0.59	NS
3-3D/3-3DA	0.73	0.0003	***	−0.24	0.31	NS

NS = non-significant.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 4 – Ratios for dental (D) to dentoalveolar (DA) movements for the customized arch form and the preformed arch form groups.

Dimension	Customized arch			Preformed arch		
	D Δ (mm) T2 − T1	DA Δ (mm) T2 − T1	Ratio D:DA	D Δ (mm) T2 − T1	DA Δ (mm) T2 − T1	Ratio D:DA
7-7	1.38	0.44	3.14	2.03	0.89	2.28
6-6	1.23	0.07	17.57	1.76	1.2	1.47
5-5	1.16	0	Undefined	1.78	1.79	0.99
4-4	0.9	0.49	1.84	1.76	1.8	0.98
3-3	0.47	−0.26	−1.81	1.14	0.85	1.34
		Mean ratio	5.18			1.41

D: dental dimension; DA: dentoalveolar dimension.

but only in the area of the second molar for the customized archwire group (Table 2). This seems to indicate that the dentoalveolar area or the WALA Ridge is not immutable, but can be changed as demonstrated by the use of preformed archwires that are expansive beyond the dentoalveolar area. In addition, an increase in dental arch width using arch wires customized to the WALA Ridge results in less change in dentoalveolar anatomy when measured at the WALA Ridge. Andrews hypothesized that the center of rotation of the mandibular teeth is at or near the level of the WALA Ridge [35]. He further suggested that by using archwires customized to the WALA Ridge, expansion of the dental arch occurs by buccal tipping of the teeth around their center of rotation with no significant change at the WALA Ridge. In the customized arch group, the teeth were uprighted, but the root portion remained in a reasonably consistent position. Andrews would argue that the teeth simply uprighted around or near the center of resistance. In the preformed group, the teeth also uprighted, but the root portion moved facially as well and the dentoalveolar measurements increased to document that change. Essentially, the customized arch form teeth moved with uncontrolled tipping and the preformed arch form teeth moved with controlled tipping in conjunction with the well known general extrusive movements of the appliances. This is demonstrated by the dental to dentoalveolar ratios shown in Table 4. From those data it is apparent that in the custom archwire group the crowns moved buccally in a large ratio relative to the center of resistance as documented by the dentoalveolar points. In the preformed group, the ratio was three to five times less and approached nearly one. This indicates that the teeth were moving with both the crown and dentoalveolar points going in a buccal direction. Research is necessary to determine the periodontal implications of expansion of teeth beyond their centered position over basal bone.

The current study has several limitations. The size of the control group was smaller because of the limited number of subjects in the Ohio State University Growth Study to match the experimental groups. However, since there were significant differences between one of the treatment groups and the control group, there is an indication that the control group did have adequate power. In addition, there were differences between the Andrews and the Damon system such as the crown inclination or torque prescription which may influence the buccalingual tipping of the molars. The final archwire size of the two treatment groups also differed by .002″ in the vertical dimension.

5. Conclusions

The dentoalveolar or WALA Ridge arch width can be maintained when customizing arch wires for a patient's mandibular dental arch shape. Significant change in dental arch width can take place during treatment without significant changes to the dentoalveolar area measured at the WALA Ridge when archwires are shaped to the WALA Ridge. However, dental arch expansion with different biomechanical movements will result in greater expansive dentoalveolar changes measured at the WALA Ridge. If an operator's intention is to custom shape a mandibular arch form, sometimes involving dental arch expansion through uprighting of teeth only, the WALA Ridge provides a useful landmark to use in customizing the form of the arch wire as opposed to an otherwise subjective arch shape.

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