ORIGINAL ARTICLE

Comparison of commercially available preformed archwires with average natural arch forms

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Abstract

Objective: To compare the dimensions of commercially available preformed archwires with natural arch forms of Pakistani subjects.

Method: The cross-sectional study was conducted at the Department of Orthodontics, Armed Forces Institute of Dentistry, Rawalpindi, Pakistan, from September 2019 to February 2020, and comprised maxillary and mandibular dental casts of orthodontically untreated subjects that were evaluated to obtain arch dimensions at the canines and first molar levels with the help of digital Vernier calipers. Bracket-archwire assembly was constructed to accurately measure widths from bracket-slot points at both the canine and molar levels in an attempt to mimic clinical archwire-bracket interface. Canine and molar depths were also recorded for accurate estimation of the digitised archwire widths at the aforementioned levels. Data was analysed using SPSS 25.

Results: Of the 52 subjects, 26(50%) each were males and females with age ranging from 12years to 35 years. The archwires evaluated for maxilla were significantly wider at canines and first molars compared to the canine and molar dimensions of the dental casts obtained from the subjects ($p<0.05$). For mandible, significant differences were found at the canine level where archwires exhibited greater dimensions than mean intercanine widths of the subjects ($p<0.05$).

Conclusion: Commercially obtainable preformed archwires were inconsistent with diverse arch forms manifested in subjects with almost ideal occlusion. Therefore, utilisation of these archwires may create unwarranted wider dimensions of the arch form, especially in the intercanine region which can influence post-treatment retention, stability and facial aesthetics.

Keywords: Arch form, Canine depth, Intercanine width, Intermolar width, Molar depth, Preformed archwire, Stability.

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Introduction

Changes occurring in dental arch dimensions either from growth or as a consequence of treatment are of paramount importance to an orthodontist. For better retention planning and treatment stability, the clinician needs to have a good understanding of these changes.[1] Orthodontic literature has laid a great focus on relapse of corrected malocclusion. A review reported that only 30% of the orthodontically treated cases preserved their alignment after 10 years of orthodontic therapy, which further reduced to 20% after 20 years post-retention.[2] Factors like progressive jaw growth, malocclusion severity, incisors angulation over the basal bone, arch dimensions and retention protocol may contribute to relapse after comprehensive orthodontic treatment.[3] Amongst these, any alteration made to the jaw base is a well-known predictor of dental relapse.[4] Therefore, Housley et al. highlighted the importance of correct archwire selection during treatment in order to preserve pre-treatment form of the arch.[5] This also increases the efficiency of orthodontic tooth movement and lessens the tendency of relapse.[6]

Alveolar bone and supporting tissues influence the initial shape of dental arches. Later, as the teeth erupt into occlusion, perioral musculature and associated functions further affect its morphology.[7] To date, configuration of dental arch is controversial as methods used for measurement vary among professionals.[8] However, tapered, ovoid and square have been reported as the three main arch form shapes. Bhowmik et al. listed main clinical factors that modulate dental arch dimensions, which include arch depth, cross-arch width and arch perimeter.[9] Adequate evidence exists regarding return of inter-canine (IC) and inter-molar (IM) widths to pre-treatment state when original arch proportions are disrupted during treatment, along with periodontal breakdown.[10,11]

With the advent of vast variety of appliances, several archwire forms have been introduced to serve different purposes. Although certain studies indicated marked differences in original arch dimensions and commercially available prefabricated archwires,[12,13] limited amount of attention has been paid to the rationale behind these archwires. Archwires are an important technical component of orthodontic therapy, capable of generating forces through bands and brackets to bring about tooth movements. When highly elastic nickel-titanium (NiTi)

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archwires were introduced, they quickly gained popularity because their exceptional springiness allowed the practitioners to make use of rectangular wires with larger cross-section in the early levelling and aligning phase of the treatment.[14,15] As the treatment advances, heavier rectangular NiTi or even heat-activated NiTi followed by stainless steel (SS) archwires are brought into action. These archwires possess high tensile strength values and, if used during treatment for a prolonged period, can substantially influence the form of natural dental arch.

Many clinicians support the individuality and uniqueness of arch forms and are of the view that arch form should be acknowledged as part of a morphological human pattern.[16-19] The modern straight-wire design or pre-adjusted edgewise appliance therapy, employs brackets with built-in prescriptions and archwires that come in varying shapes and abundant sizes. These varieties are processed and supplied by manufacturers belonging to different regions of the world. Majority of commercially available preformed archwires in Pakistan are imported from manufacturers of the United States, China or other countries and are believed to be standardised according to their own population.[20] Arch forms differ among people belonging to different demographic regions and age groups as supported by studies.[21,22] Therefore, archwire selection is crucial and clinicians should carefully choose archwires of appropriate dimension for an individual case. The current study was plannd to determine the arch dimensions of male and female samples in Pakistani population, and to estimate whether commonly available preformed orthodontic archwires correspond to the mean natural arch form of these subjects.

Materials and Methods

The cross-sectional study was conducted at the Department of Orthodontics, Armed Forces Institute of Dentistry (AFID), Rawalpindi, Pakistan, from September 2019 to February 2020.

After approval from the institutional ethics review committee, the sample size was estimated on the basis of an earlier study, which reported a mean maxillary IC width of 35.22±1.54mm in male subjects and 33.49±1.49 mm in female subjects.[23] Study power was kept at 90% and α value 0.01. The sample was raised using stratified sampling technique. Those included had no prior orthodontic procedure, balanced facial aesthetics, Angle Class I molar, canine and incisor relationship with normal overjet and overbite, symmetric arch form and arch length discrepancy (ALD) not exceeding 3mm, complete set of permanent teeth excluding third molars, minimal to no restorations and negligible attrition. Patients with craniofacial abnormalities or syndromes, history of medications that may have influenced craniofacial growth, anomalies of tooth formation and eruption, and presence of unilateral or bilateral cross-bite were excluded.

After taking informed consent from all the subjects, impressions of both maxilla and mandible arches were recorded with perforated impression trays loaded with alginate impression material under aseptic conditions. Dental stone was poured on the recorded impressions and enough sets of dental casts were obtained for analysis satisfying the inclusion criteria.

For the estimation of arch form dimensions, a bracket height gauge (precise positioning of 0.022 brackets; Ortho Organizers GmbH) was made use of to accurately mark 12 clinical bracket points on the facial aspect of teeth with a lead pencil (DOLLAR, my™ pencil wow, Asia, Pakistan). These points were located at the centre inciso-gingivally and mesio-distally along the facial axis (FA) of the tooth. Industrial IP67 4Cr13 stainless steel digital Vernier calipers (WW-IP67) with the range of 0-150 mm and resolution of 0.01mm were used to measure four different arch form parameters: IC width, the measure of distance between right and left canines at FA points; IM width, the measure of distance between right first molar and left first molar FA points; canine depth (CD), the measure of a perpendicular distance from the midway point between the line connecting the FA points of canines to the origin between the central incisors; and molar depth (MD), the measure of a perpendicular distance from the midway point between the line connecting the FA points of first molars to the origin between the central incisors" (Figure 1).[23]

For the estimation of arch form dimensions with bracket-archwire assembly, metal brackets (Roth 0.022 x 0.028-in slot; Di-MIM Mini Twin by Ortho Organisers, Inc. GmbH) of both maxillary and mandibular central incisors, canines and first molars were selected to obtain thickness of respective bracket bases in order to compute the distance between FA point and the bracket slot (BS) point. These brackets

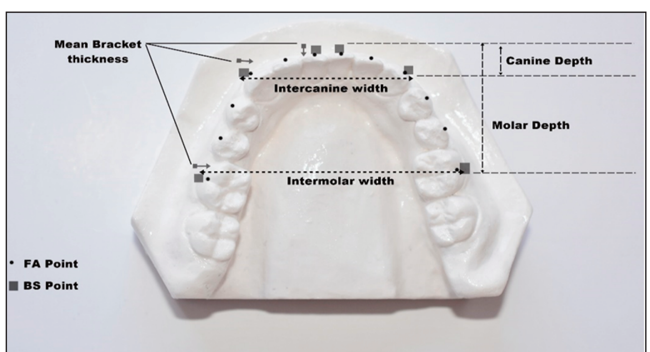

Figure-1: Construction of bracket-slot (BS) points, and the reference points (FA) for calculation of widths and depths at the canine and molar levels on obtained natural dental casts.

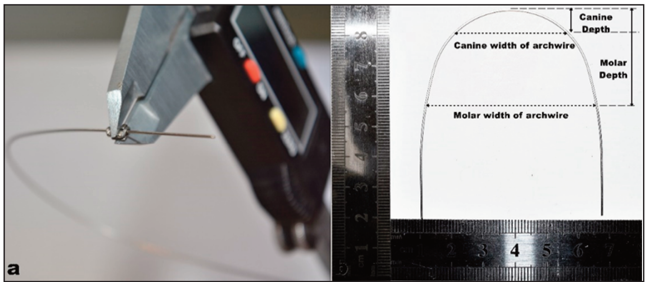

Figure-2: a) Measuring bracket thickness with Vernier calipre. b) Archwire widths determination at the cuspid and first molar levels.

were then ligated with elastomeric modules to a 0.017 x 0.025-in NiTi archwire (Ortho Organisers, Inc. GmbH) and the distance between the centre of the bracket mesh base and the BS was quantified for central incisors, canines and molars for both the arches separately with the aid of digital Vernier calipers (modified in 0.01mm resolution) by the main investigator (Figure 2A). The aforesaid archwire size was appointed for all commercially obtained archwires used in the current study for evaluation.

The BS point represents the position of bracket base slot on the facial surface of tooth. It is constructed at a point extending externally from the corresponding FA point. This BS point served as a reference for calculation of IC width-B (ICB), IM width-B (IMB) canine depth-B (CDB) and molar depth-B (MDB) with bracket-archwire assembly of the obtained samples.

For the determination of archwire dimensions, 10 maxillary and 10 mandibular archwires of the same dimension (0.017 x 0.025-in NiTi) (Table 1) were scanned along with 2mm rulers using an all-in-one scanner (HP Deskjet F2480) keeping resolution at 600dpi to minimise any magnification inaccuracy (Figure 2B). Archwires were obtained from 6 different local suppliers that are frequently being used at various orthodontic facilities in Pakistan based on convenience sampling technique. The mean canine depths (maxilla: 9.71±2.84; mandible: 6.16±2.19) and first molar depths (maxilla: 31.99±3.54; mandible: 25.03±4.30), as estimated from the maxillary and mandibular casts of the subjects were used as reference to measure the IC width-A (ICA), and IM width-A (IMA) of the obtained archwires. The points located lingual to the archwire at which the lines formed at the level of mean canine and first-molar depths intersected, were connected to obtain the required measurements.

The digitized archwires were analysed using an image-editing software (Adobe Photoshop, Version 21, San Jose, Calif) to remove any possible magnification or human error.

To achieve accuracy, readings of dental casts and archwires were taken by the same observer twice and each measurement was taken to the nearest 0.5mm. Furthermore, the measurements were re-recorded after an interval of 15 days to determine intra-examiner reliability. Cohen's Kappa coefficient was used to calculate intraobserver variability and the readings obtained ranged between 0.89 and 0.95. Also, a transparent plastic ruled grid, which served as guidelines while measuring arch depths, was used to further minimise any error during calculation.

Data was analysed using SPSS 25. Mean and standard deviation values; median, first quartile (Q1) and third quartile (Q3) readings of the arch widths with and without bracket-archwire assembly were acquired using Mann-Whitney U test. The same non-parametric test was utilised to generate comparison between mean with standard deviation values, median, first (Q1) and third (Q3) quartile values of natural arch widths of both maxillary and mandibular jaw bases with bracket-archwire assembly and their corresponding archwires. Non-parametric tests were used as the distribution of natural arch widths and commercially obtained archwire widths did not fit the normal distribution. $P<0.05$ was considered statistically significant.

Results

Of the 52 subjects, 26(50%) each were males and females with age ranging from 12 years to 35 years. Normal arch proportions measured were relatively wider for males than

Table-1: Commercially available preformed archwires evaluated.

Sample	Manufacturer	Archwire form
1	Ortho Organizers, Inc. GmbH	Oval arch form (Upper) Oval arch form (Lower)
2	Foshan Vimel Dental Equipment Co. Ltd, China	Orthoform Ovoid (Upper) Orthoform Ovoid (Lower)
3	Guber Dental Technology Co., Ltd., Shanghai	Ovoid Form (Upper) Ovoid Form (Lower)
4	Med Kraft Orthodontics, Dallas, Texas	Natural Form (Upper) Natural Form (Lower)
5	Denxy Technology Co., Limited, Hu Nan-China	Orthoform Ovoid (Upper) Orthoform Ovoid (Lower)
6	3M Unitek, Monrovia, Calif	Ortho Form I (Upper) Ortho Form I (Lower)
7	3M Unitek, Monrovia, Calif	Ortho Form II (Upper) Ortho Form II (Lower)
8	Otho-Care (UK) Ltd	Euroform Archwire (Upper) Euroform Archwire (Lower)
9	Dentaurum, Ispringgen, Germany	Proform Arch Shape (Upper) Proform Arch Shape (Lower)
10	Lancer Orthodontic, Vista Calif	Archwire (Upper) Archwire (Lower)

Sample 1 - 10 denotes the preformed archwires used of respective maxillary (upper) and mandibular (lower) dentition for comparison.

Table-2: Mean arch dimensions of male and female subjects (n = 52).

Sample	Parameters	Mean ± SD	Median	Q1	Q3
Arch width measurements made on natural dental casts (mm)					
Maxilla	Intercanine width (IC)	34.85 ± 3.90	35.12	32.13	37.44
	Intermolar width (IM)	52.90 ± 4.17	53.96	50.74	55.61
	Canine Depth (CD)	9.71 ± 2.84	9.34	7.77	11.98
	Molar Depth (MD)	31.99 ± 3.54	31.51	29.12	34.24
Mandible	Intercanine width	28.05 ± 3.35	27.98	26.45	29.41
	Intermolar width	48.77 ± 3.70	49.12	47.53	51.42
	Canine depth	6.16 ± 2.19	6.15	4.74	7.49
	Molar depth	25.03 ± 4.30	25.08	22.87	27.31
Arch width dimensions with bracket-archwire assembly (mm)					
Maxilla	Intercanine width (IC-B)	37.61 ± 3.75	37.80	34.81	40.12
	Intermolar width (IM-B)	55.68 ± 4.06	56.64	53.42	58.46
	Canine depth (CD-B)	11.59 ± 2.39	10.97	9.53	13.61
	Molar depth (MD-B)	33.62 ± 3.54	33.14	30.75	35.87
Mandible	Intercanine width	29.33 ± 3.35	29.26	27.73	30.69
	Intermolar width	50.03 ± 3.70	50.38	48.79	52.68
	Canine depth	8.15 ± 2.19	8.14	6.73	9.48
	Molar depth	27.02 ± 4.30	27.07	24.86	29.30

SD: Standard deviation; Mann-Whitney U test.

Table-3: Comparison of arch width dimensions between normal dental arch with bracket-archwire assembly and preformed archwires of both maxilla and mandible.

MAXILLA Parameter	**Dental Arch width with bracket-archwire assembly (mm) n_1= 52**				**Preformed archwire (mm) n_3= 10**				***p*-value**
	Mean±SD	Median	Q1	Q3	Mean±SD	Median	Q1	Q3	
Intercanine width	38.34±3.88	38.74	35.71	40.98	42.16±1.84	41.32	40.69	44.58	0.000**
Intermolar width	56.12±3.88	56.82	54.50	58.86	58.45±1.33	58.44	57.35	59.57	0.014*
MANDIBLE Parameter	**Dental Arch width with bracket-archwire assembly (mm) n_2= 52**				**Preformed archwire (mm) n_4= 10**				***p*-value**
	Mean±SD	Median	Q1	Q3	Mean±SD	Median	Q1	Q3	
Intercanine width	30.20±3.72	29.61	28.14	32.40	34.75±1.61	34.25	33.57	36.36	0.000**
Intermolar width	50.16±3.44	50.70	48.93	52.41	50.86±1.43	51.62	49.50	52.01	0.738

Maxillary natural arch widths (n_1) = 52, mandibular natural arch widths (n_2) = 52, maxillary archwires (n_3) = 10, mandibular archwires (n_4) = 10, $^*p < 0.05$, $^{**}p < 0.01$; Mann-Whitney U test. SD: Standard deviation.

females, but the results were statistically non-significant (*p*>0.05). Mean CD (maxilla: 9.71±2.84; mandible: 6.16±2.19) and mean MD (maxilla: 31.99±3.54; mandible: 25.03±4.30) of both the arches were used as reference points (Table 2). The archwires evaluated for maxilla were significantly wider at canines (42.16 ±1.84 mm; *p*=0.000) and first molars (58.45±1.33 mm; p=0.014) compared to the canine and molar dimensions of the dental casts obtained from the subjects (37.61±3.75 mm, 55.68±4.05 mm respectively). For mandible, significant differences were found at the canine level where archwires (34.75±1.66 mm; *p*=0.000) exhibited greater dimensions than mean IC widths (29.33±3.35 mm) of the subjects (Table 3).

Samples 5, 6, 8 and 10, out of the 10 samples of archwires used for comparison, showed a little close conformity to mean canine and molar width of the subjects for maxillary arch. For mandibular arch, all the wires showed marked deviation from the mean value, but samples 5, 6, 7, 8 and 10 were somewhat closer to the mean value of the subjects. However, molar widths of all the 10 samples obtained from the suppliers conformed to the range of mean IMB upon evaluation.

Discussion

Distinct and diverse preformed archwires can be acquired commercially for use in daily orthodontic practice. The dimensions of a natural arch tend to fluctuate not only by age, but also among various ethnicities. Studies on Colombians, Koreans and Japanese reported wider dimensions of the arch forms in comparison to our subjects.[24-26] Hence, it is impractical to generalise an arch form since it cannot be instituted as a template for all populations. Under theoretical consideration, an orthodontist should appropriately select the shape and size of archwire that best conforms to individual arch in order to attain stable treatment outcome. Prefabricated archwires are designed to fit the most commonly occurring natural dental occlusion, allowing reduced chair-side time for adjustment and selection of suitable archwire. Hence, the goal of the present study was to determine whether these commercially available archwires are fit for commonly occurring dental arch form in our population or not.

During comprehensive orthodontic therapy, beta titanium (Titanium Molybdenum Alloy [TMA]) or SS archwires are used that can be modified to cater to individualised arch form, and to minimise chances of undue changes during treatment as they possess good formability. The flexible NiTi archwires on the other hand are difficult to remodel due to superelastic property and poor malleability. Therefore, if these preformed wires are not consonant with an individual's arch shape, they may alter the original arch form, enabling unwanted repercussions.[27]

A survey of literature indicated that only few studies have been conducted,[25-27] especially on Pakistani population.[23] The main focus of most of them was on the mandibular arch and archwires only. Therefore, the current study aimed at expanding the horizon and evaluated conformity of preformed archwires for both maxillary arch and mandibular arch in a sample of Pakistani subjects.

Pre-treatment IC width is critical to maintain in order to scale down the orthodontic relapse tendency. The estimated results for canine and molar widths with bracket-archwire assembly of population under study are in contradiction with reported values.[9,26] The disparity in results among studies may be due to dissimilarities in thickness of bracket-archwire assembly used, as any change in antero-posterior position of the archwire at the level of teeth can greatly affect calculated dimensions.[26] So it is safe to say that already reported canine widths (with bracket-archwire assembly) cannot be considered meticulous representation of natural arch proportions and variability may occur if a different bracket prescription is used. To overcome this diversification and generate a better assessment, the mean natural IC and IM widths of our subjects were also reported (Table 2). These values can be used to perform necessary adjustments in cases where a bracket system with different bracket base width is put to use.

Although arch dimensions observed for male samples were slightly larger in dimensions compared to female subjects, the data was statistically not significant. This finding was contradictory to a previous study that reported significant difference in arch widths between the two groups.[23] All 20 preformed archwires were found to be significantly wider in the canine region compared to the mean ICB region found in the subjects. Conversely, when the molar widths were compared, maxillary archwires were wider in dimensions than mean maxillary IMB, but mean mandibular archwire dimensions showed no significant differences in width in comparison to mandibular width.

Heavier NiTi archwires have a tendency of changing the IC width during alignment when incorporated in treatment for a longer duration so these should be used with great caution, especially in non-extraction cases.[23]

Other studies have documented both wider and narrower dimensions of the preformed archwires, unlike the forms we observed in our population.[9,23,25,26] Ethnic variations, choice of different archwire brands or shapes, and use of a different bracket-base system may be the factors responsible for causing differences in results among these studies. In the present study, archwires that are often used and supplied by local companies at various orthodontic centres across the country were examined (Table 1). Also, it is a common observation that clinicians tend to use archwires that are generally of a popular brand for almost all the patients. These archwires may not be suitable for a particular patient as they do not possess sufficient variations. If wider archwires are used for longer duration, they not only cause unnecessary expansion of the dental arch, but also ensure post-treatment instability.[4,27,28] On the contrary, under special considerations, wider archwires may be required in cases where that expansion is desired.

Out of 10 pairs of samples, 4 samples; 5, 6, 8, and 10 (Denxy Tech. Orthoform Ovoid, 3M Unitek Orthoform I, Ortho-Care Euroform and Lancer Orthodontic archwire respectively) showed a little close conformity to mean canine and molar widths of the subjects for maxillary arch. For mandibular arch, all the wires showed marked deviation from the mean values, but samples 5, 6, 7, 8 and 10 (Denxy Tech. Orthoform Ovoid, 3M Unitek Orthoform I, 3 M Unitek Orthoform II, Ortho-Care Euroform and Lancer Orthodontic archwire respectively) were somewhat closer to the mean value of subjects under study. However, none of the samples accurately conformed to either mandibular or maxillary arch forms of the subjects.

The current study highlighted the importance of re-designing preformed archwires as range available for selection is not adequate enough to cover such diversified natural human dental arch forms. Ideally, NiTi archwires conforming to the population's dimension should be manufactured. Until these customised archwires are produced, the dimensions of archwires should be manipulated and adapted before use. Individualisation of the form of some NiTi archwires is also possible for martensitic active alloys that can be transformed using chair-side techniques without distorting the superelastic property.[29,30] This can help reduce the changes inflicted in the arch form of an individual, thereby minimising the tendency for post-treatment relapse.

Parameters evaluated in the current study were limited as first premolar, second premolar and second molar widths were not taken into consideration. Furthermore, various arch form designs, like ovoid, tapered and square, occurring in different populations can be studied. Comparison of arch forms and dimensions of people belonging to different ethnic groups can also be made in future studies. But individualisation concept will still perish as vast variation criteria in patients cannot be met by a few preformed archwires available.

Conclusion

All the mean archwire dimensions at the canine level were generally found to be wider for both male and female subjects. The mean mandibular archwire widths at the first molar level were similar in dimension to that of mean molar widths of the subjects. Utilisation of such wider archwires should be avoided, especially for IC width maintenance as these may compromise treatment stability and increase chances of relapse after orthodontic treatment. The variation in commercially obtainable preformed archwires does not wholly correspond to the range of diversity found in natural arch forms. Therefore, customised archwires that fit perfectly according to an individual's arch form can be used for better treatment outcome or archwires with good formability can be altered to control arch width and minimise unwarranted modifications.

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