An overview on dental arch form and different concepts on arch coordination in orthodontics

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Abstract

One of the most important characteristic of dentition is dental arch form. In orthodontic treatment, it is crucial to understand each individual dental arch for diagnosis and treatment planning and try to preserve it throughout the treatment to achieve a higher stability. Additionally, it is important to maintain a well-established coordination between maxillary and mandibular dental arch to have a perfect functional occlusion. In orthodontics up to now, different definitions have been proposed for human dental arch form and methods for coordinating dental arches. The aim of this study was to gather and compare these concepts. The available data were categorized and discussed in five different domains: Arch Form (history and recent concepts), Factors affecting dental arch form, Characterization of arch form, Coordination of upper and lower arches and arch wire selection and arch form.

Keywords: Dental arch form, Arch coordination, Arch wire

There is a close relationship between dental arch form and normal occlusion. The size and shape of arch form is a significant factor in orthodontic diagnosis and treatment planning. To characterize the form and size of dental arch, different parameters have been introduced such as arch circumference, arch width and depth [2,3].

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In fact, arch form as a part of a whole dentition is a morphologic pattern of each individual which is controlled by the underlying basal bone in one hand and the balance between circumoral and intra oral muscles on the other hand [4,5]. Accordingly, the importance of understanding each patient's arch form and trying to preserve it during orthodontic treatment has been strongly mentioned by previous authors.[6,7] It is now evident that any changes in intercanine width can significantly increase the risk of post retention relapse and preservation of arch form is an indispensable factor for stability of treatment.[8,9]

In order to predetermine the shape of arch, some geometric methods have been proposed.[10,2] and also most commonly, arch forms have been categorized into square, ovoid and taper types 11,12 Along with the characterization of each arch, the coordination between upper and lower arches is crucial to achieve an ideal occlusion. 13 Any maladaptation of arches can lead to sagittal and transverse discrepancy which in turn causes alveolar bone resorption, periodontal problem and functional impairments. [14,15]

With standard edgewise appliances arch form and arch coordination was the basis of archwire fabrication by orthodontists but when pre adjusted edgewise appliances were introduced and preformed archwires became available, individualization of archwires for each patient was ignored by some orthodontists. This is especially true about nickel titanium (NiTi) prefabricated archwires that cannot be altered in shape by orthodontists at the chair-side.[16] It is prudent that in selection of a suitable set of prefabricated NiTi archwire special attention be paid on the pretreatment patient's dimensional arch form and also a proper coordination should be established in adjusting stainless steel archwires.

Thus, the importance of understanding the characterization of a proper archwire and the exact way to correctly coordinate the maxillary and mandibular arch wires is evident for both orthodontists and manufacturers. This study was done with the aim of providing a comprehensive pack of information about dental arch forms and methods of proper arch coordination.

Arch Form

History: From the advent of modern orthodontics, special attention was paid to dental arch form. The Bonwill-Hawley arch form was one of the traditional ideal arch forms for many years. In incisor region, it contours a circle with the radius equal to sum of mesiodistal widths of the incisors. From cuspid to molar, it follows a straight line [17]. (Fig 1)

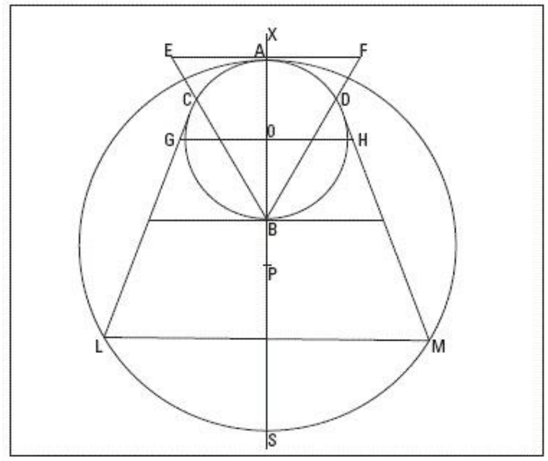

Fig 1: The Bonwill-Hawley arch form

Edward Angle [1] objected the posterior part and stated that a straight line existed from the cuspid to the mesio-buccal cusp of the first molar, however, there was a natural curvature in the molar region. Chuck noted the variation of human arch form and pointed out arch form can be square, round, oval tapering, etc. he suggested that the bicuspid regions should be wider than the cuspids to prevent excessive expansion of the cuspids [18]. Boone, in 1963, proposed superimposition of the Bonwill-Hawely arch form on a millimeter template to construction an individualized edgewise arch. [6] Thus, over the years, the Bonwill-Hawely arch form has been the most consistently used arch form as a beginning template for edgewise orthodontics. McConaill stated that in considering the line of occlusion, it would be impossible for an ellipse and parabola to meet one another at every point and wouldn't be functional. He stated that the catenary curve fit most cases and could be taken as ideal curve of common occlusion.[19] The catenary curve is formed simply by suspending a chain of appropriate length from two points of varying width for example width of the most distal molars in the arch form. (Fig 2)

Fig 2: The catenary curve

Scott and Burdi believed that human basal bone of the maxilla and mandible had a catenary curve which established at early stage of utero life and remain constant [20,21]. The catenary curve creates a rather tapered arch form and many of the tapered arch forms provided by manufacturers today are based on the catenary curve. According to White [5] the catenary curve corresponded well in 27% of subjects with untreated ideal adult occlusions and moderately in 46%. Brader [22] mentioned that dental curve represent an equilibrium by the counterbalancing forces of the tongue and circumoral tissues.He believed the geometry of arch form is approximated by the curvilinear properties inherent in the trifocal ellipse with the teeth occupying only the portion at the constricted end of the curve. (Fig 3)

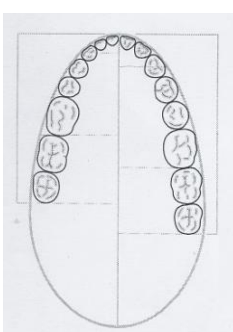

Fig 3: Brader utilized the anterior portion of a trifocal ellipse to establish arch form.

He recommended an arch guide with five arch form, from which, the selection was according to arch width at mandibular second molar. The maxillary arch form was selected one size larger. However, many clinicians found that his arch form created excessive narrowing in the cuspid region of many patients and led to excessive wear of the incisal portion of the cuspids. Remsen observed that in “normal occlusion” parabola best represent the anterior curvature of the dental arch but he stated that an arch which fits a precise pattern was the exception rather than the rule. [23]

Recent concepts: The authors of the McLaughlin- Bennett-Trevisi technique, categorized the arch forms to 3 main clinically described shapes: square, ovoid, and tapered.[24] (Fig 4)

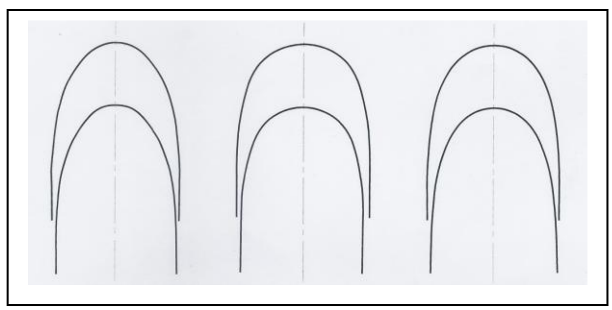

Fig 4: Three common arch form: a) tapered, b) square and c) ovoid

The differences between these arch forms are in their anterior curvature and intercanine width. The preformed arch wire with these shapes has been reported to be different in these parameters up to 6 mm. For most patients (approximately 45%), ovoid archwire fitted best and tapered archwires was suitable for 40% of patients. However, square was the least commonly used in clinical practice (15%). Tapered archwire with the least intercanine width should be used in patients with a narrow apical base. It is also suggested to use this type in cases with gingival recessions on the canines and premolars.24 Trivino et al.25 defined 8 forms for mandibular arch, each of them divided into 3 subgroups: small, medium, and large sizes. The most common form was the medium size of the form that had flattening in the anterior curve region and the origin of the curvature at the distal region of the lateral incisors. 10% of patients had an arch form the anterior teeth roundly arranged, as in an ellipse.25 Conversely this type was reported as the most observed form by Ricketts 26 and Telles 27.

Braun et al. 9 proposed the mathematical Beta function as an accurate planar representation of normal arch form (the correlation coefficient between the data measured from dental casts and those expressed by beta function was $r = 0.97$ for the maxilla, and $r = 0.98$ for the mandible). They described six equations for maxillary and mandibular arches in class I, II and III patients which were a function of arch depth and arch width. The curve of each arch can be plotted by knowing two parameters: width of the dental arch at the second molar region and arch depth. (Fig 5)

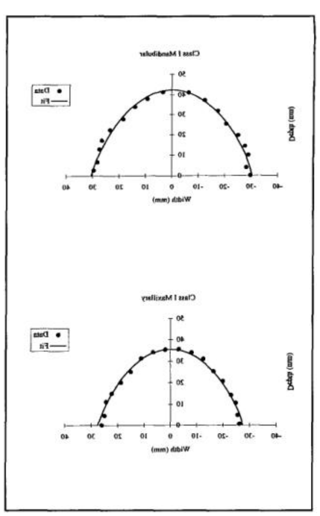

Fig 5: Angle Class I maxillary and mandibular arch with beta function

They stated that in class III occlusions, both mandibular and maxillary arches are wider than class I which in turn were wider than class II. While arch depth of maxilla was equal in three classes it was more in class I than class II or III in mandible. [9] Noroozi et al.[28] presented a model that was defined by 4 parameters, by the depths and widths of the dental arch at the canine and second molar regions. They claimed that their model would be flexible at the anterior as well as posterior regions of a dental arch and therefore can be an accurate substitute for the beta function in less common, i.e. square or tapered, forms of the human dental arch. They offered the equation of $y = ax6 + bx2$, by measuring the 4 parameters of a dental arch including inter-second molar width (Wm), inter-canine width (Wc), second molar depth (Dm) and canine depth (Dc) [28].

Recently, development of 3-dimensional (3D) virtual technology has made it possible to measure most arch-form parameters accurately from 3D virtual models. The reliability of measurements is comparable with plaster casts. [29,30] The 3D data allows us to make more precise and completely individualized measurements and arch form of each patients can be determined in details by 3D analysis.[31]

Factors affecting dental arch form: Angle believed that arch form varies within the limits of normal, according to race, type, temperament etc., of the individual.[17] Hellman investigated the skull of apes and human beings and found no relation between the size of teeth and the form and shape of dental arches. 32 Izard proposed a method of arch predetermination on ratios between arch width and facial depth. 33 Nowadays it is believed that arch form and shape are related to a person’s anatomic dimensions of the craniofacial skeleton, malocclusion type, ethnicity, and sex.[12, 34] Basically, the size and the shape of a dental arch are determined by the configuration of the underlying alveolar bone. In fact it is a product of naturally established balance of the jaw and muscle forces. It has been mentioned by some studies that arch widths of the maxilla and the mandible varies in Class I, Class II, and Class III malocclusions. The differences were mainly reported in the posterior regions. According to some investigations, Class II patients appear to have narrower maxillary and mandibular dental arches relative to normal class one occlusion. In Class III subjects although maxillary arches were narrower than normal, the mandibular arches were wider.[35,36] Slaj *et al*.[31] believed that dento-alveolar classes are best distinguished by comparing anterior segment of mandible and posterior segments of maxilla. It appears that Class III patients have more square dental arch shapes, and Class II patients are more tapered. An approximately 5% of sexual dimorphism in size in skeletal bones and dental arches have been reported, with females having smaller dimensions. [37]

Characterization of arch form

What factors should we take into account when we want to define the arch form of a patient and categorize it? According to a recent study on discriminant factor analysis of dental arch, the principal factors that can be used to categorize a patient's arch form are arch width and depth, and dental perimeter. [1] They concluded that dental arch form in patients with mild and moderate crowding are mostly defined by maxillary inter-molar width and mandibular inter-canine width. In other words, maxillary arch form is more distinguishing in the posterior segment and mandibular arch form in the anterior segment. In comparison to arch width, arch depth was believed to contribute less in the differentiation of the dento-alveolar classes and sexes1. The Class III group had the most detectable arch form, and the Class I group had the least detectable arch form. [31]

Various landmarks have been used for measurement of arch dimension. The most common landmarks included incisal edge and cusp tip38, centroid of the occlusal surfaces or developmental fossa or grooves 39, contact points, and clinical bracket points [11,12]. In order to characterize an arch form some parameters should be measured and reported. The most common parameters are arch width parameter such as: inter-canine width (ICW), inter-prermolar width, (IPW) and inter-molar width (IMW); arch depth which can be divided into inter-canine depth (ICD) and inter-molar depth (IMD); canine W/D ratio, molar W/D ratio etc.

Several authors have categorized arch forms into tapered, ovoid, and square shapes to evaluate their characteristics.[10-12] However; most of them limited their evaluations to the mandibular models only. In a recent study with 3-dimensional virtual models, Kim et al. concluded that the extension to the first premolar was sufficient to classify arch form types [9]. Lee et al. 40 developed a method to classify dental arch forms by cluster analysis. Three types of arch forms were identified in both maxilla and mandible: Narrow, middle and wide. Most of patients had middle-size arch. Proportional variables were measured and resulted that: the arch width to arch depth ratio were indicator of broader vs. narrower arches; Lower values of the inter-canine to inte-rmolar width ratio represented tapered arch form while the ratio in square arch form is higher. Anterior curvature was calculated by dividing sum of anterior tooth sizes [3-3] to inter-canine width and showed that the narrow arch type in both the maxilla and the mandible has convex arch forms rather than flat curvature compared with the wide type. Moreover; in narrow arch the value of arch width to arch depth ratio was lower while value of ICW to IMW ratio was higher. Narrow arch had the smallest ICW and IMW, while the wide arch form showed not only the largest ICW but also had much greater IMW. Thus, the value of ICW to IMW ratio for the tapered and convex arch form was higher.[40]

Coordination of upper and lower arches

Adjustment of upper and lower arches with each other is of a great importance to achieve stable functional and esthetic results and it is essential to maintain an appropriate overjet throughout the whole arch.[13] McLaughlin et al. [24] applied imprints of brackets in the wax bite to measure the optimum overjet and stated that in order to coordinate arch wires, upper archwires should be 3 mm wider than the lower one. However, Braun et al. [16] evaluated spatial coordinates of the labial and buccal dental/bracket interfacing surfaces in both arches and concluded that coordination with ‘‘3 mm” overjet through whole areas between the upper and lower bracket slots is not accurate. Cordato 41, 42 proposed a mathematical model to calculate the overjet of the anterior segment according to some parameters including the sum of tooth widths in each arch, spacing, crowding, angle of the arc of each arch, and the antero-posterior buccal relation. He insisted that changes in overjet and overbite during and after orthodontic treatment could be predicted on the basis of tooth thickness and angles of the upper teeth. [43]

The finding of Kook et al.[12] showed a tendency toward a decreased amount of overjet from the anterior segment (2.3 mm) to the posterior one (2.0 mm) in the facial axis (FA) points which means that the arc of the posterior segment becomes relatively narrower than the anterior one in the upper arch. This finding is consistent with those of Ferrario et al. [39] who stated that the upper arch showed a ‘‘mixed’’ elliptical (anterior teeth) plus parabolic (post canine teeth) interpolation of buccal cusp tips (central incisor to second molar).

Kim et al.[9] compared the overjet among 3 arch types (tapered, ovoid and square) in normal occlusion and concluded that a significant difference was found in anterior and posterior overjet according to arch types. Tapered and ovoid arches had homogeneous anterior and posterior overjets from 2.24 to 2.59 mm and from 1.86 to 2.[18] mm, respectively. However; in the square arch form, there was a significant difference in overjet among different areas; the incisors showed a significantly greater overjet than did the posterior teeth, and the canines showed a significantly smaller overjet (2.14 mm) than did the central incisors (2.67 mm). Landmarks used for measurement of arch form and dimension did not represent the real alignment of the brackets and eventually of the archwires. It is now believed that, for precise arch coordination, alignment of the bracket is more critical than alignment of facial axis (FA) points12. Kook et al. [12] mentioned the difference between FA point of teeth and bracket slot center (BSC) points which represent the AW with regard to anterior and posterior overjet. Because the difference in the amount of overjet between anterior and posterior segments from FA points was 0.3 mm (the value was obtained by subtraction between 2.3 mm of the anterior segment and 2.0 mm of the posterior one; and values for the overjet in the anterior segment from BSC points were approximately 1.8 mm, the amounts of overjet in the posterior segment from BSC points seemed to be approximately 1.5 mm to achieve arch coordination between upper and lower archwires. Therefore, it might be recommended that the slight amount (around a half millimeter) of the offset bend be added to the second premolar area and second molar area in the archwire to allow proper arch coordination.

Arch wire selection and arch form

By introduction of nickel titanium preformed arch wires, the individuality of each patient arch form and arch size has received less attention by clinicians. Neglecting this determinant factor may results in post-treatment problems.[15]

Therefore, it seems essential to customize all commercially available archwires for each patient to improve long-term stability of our orthodontic treatment. This is attributed to great individual variability in dental arch forms. [25,44]

Braun et al 15 superimposed some popular preformed nickel titanium from alloy preformed arch wires from ‘A’ Company (San Diego, Calif), Ormco (Glendora, Calif), and 3M Unitek (Monrovia, Calif) on each of the relevant maxillary and mandibular natural forms which were described by the mathematical Beta function. They concluded that, all intercanine width and inter-first molar width of the examined preformed nickel titanium arch wire/bracket systems were larger than arch width parameters of the natural untreated arch form. The average inter canine width increase was 5.95 mm in the mandible and 8.23 mm in the maxilla which was more than the increase of intermolar width (0.84 and 2.68 mm, in mandible and maxilla respectively). This means that the larger arch width increases were confined to the anterior portion of the arch wires. In the other word, the wire ratio (molar width divided by canine width) was significantly lower than the same ratio for the natural human arch form. [15]

Felton et al [45] analyzed of the shape and stability of mandibular arch form in Class I or Class II patients and did not find a specific arch form that could characterize each class precisely. Moreover, none of the tested commercial preformed arch wires predominated for Class I and Class II non-extraction treated patients or untreated subjects with ideal Class I occlusion. In ideal occlusion the most common shape was close to Vari-Simplex archwire (Ormco) (27% of subjects). The Tru- Arch (A Company, San Diego, Calif), and the Par arch (Ormco) were the next (20% and 17% of patients respectively). Fifty seven percent of subjects in nonextraction Class I and Class II malocclusion group had an arch shape which was a combination of the Par and the Vari-Simplex arch forms before treatment. 45 The Vari-Simplex arch form was slightly narrowed in the canine region relative to Alexander’s ideal anatomic arch form. [46]

With introduction of self-ligate brackets and friction-less systems new types of archwires became commercially available. The most common self-ligate brackets system is based on Damon philosophy which believes in minimal or no expansion in the canine area and wider premolar and molar regions. These broader arch wires were designed to expand the posterior region to eliminate the dark buccal corridors in the posterior part of the mouth and improve the broadness of smile. [47,48]

In the modern orthodontic treatment, new interactive treatment planning systems such as Suresmile (OraMetrix, Richardson, Tex), Incognito (Lingualcare, 3M Unitek, Dallas, Tex), and Insignia (Ormco, Orange, Calif) are becoming more popular. These systems have claimed to offer more appropriate maxillary and mandibular arch form and arch coordination. This may results from individualizing archwires and brackets which are customize on the basis of each patient natural arch form. In case this is true, shorter treatment times and more desired results are promising. [49,50,51]

Conclusion

There are different concepts about dental arch form. Contrary to traditional concepts there is no geometric form representative for human dental arch and mathematical function on the basis of some arch width parameter can better characterize individual arch form. However, it may not be practical to apply these protocols for all patients in clinical set ups. The more recent method which is fabricating individual arch wires according to 3D models which are made on the basis of 3D scanning of each patient dentition is more advocated. Another point which must be taken into consideration is the importance of measuring arch width parameters according to facial axis point of the teeth not the anatomic points on the occlusal surface of the teeth and also according to the bracket system which are applied. One rational is that arch wires are inserted in bracket slots which are placed according to FA point and also the thickness of brackets' base impacts the location of arch wire in second order. Another reason is that the occlusal table parameters such as cusp tips and central fossa are various in the literature and there is no universal consensus on that. It is also crucial to coordinate the archwires of both jaws. There are different prescriptions for the optimum overjet throughout the dental arches. And in order to coordinate arch wires a proper overjet in anterior and posterior regions should be maintained.

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