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Arch form: A review

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Abstract---Arch form is highly individualized. The universal ideal arch form is the most persistent but exclusive task for most of the orthodontic researchers have. The basic principle of arch form in orthodontic treatment is that within reason, the patient original arch form should be preserved. Dental arch width and form are important factors for determining the success and stability of orthodontics treatment. Because of the complex problems, and relatively low knowledge of dental arches, as of today, there is no universally accepted ideal arch form. This article gives the review about different concept of arch form, importance arch form from conventional era to modern practice.

Keywords---arch form, bonwill, Hawley, catenary, brader.

Introduction

Dental arch form is the arch formed by the buccal and facial surfaces of the teeth when viewed from their occlusal surfaces. It is commonly believed that the dental arch form is initially shaped by the configuration of the bony ridge and then by tooth eruption, perioral muscles, and intra oral functional forces.² A dental arch form is initially established by the configuration of the bony ridge and then by tooth eruption, perioral muscles, and intraoral functional forces. Even though most patients with a malocclusion have an altered dental arch form, the alterations achieved with mechanics during orthodontic treatment should not affect the balance between bone and dental and muscular structures, the arrangement of these structures adjacent to teeth and jaws should be considered the limit for orthodontic movement. To minimize some of these factors, specialists have investigated the most effective approach for the correct repositioning of teeth to provide esthetics, function, and stability, and to define the size and configuration of the dental arch. (Andres De La Cruz et al., 1995)⁴ It is well established that increase in dental arch length and width during orthodontic treatment tend to return toward pre-treatment values after retention. This lack of stability of the post treatment dental arches is a difficult problem for the orthodontist. Relapse has long been recognized as being partly due to neglect in

maintenance of arch form during orthodontic treatment. The maintenance of the pre-treatment values for intercanine and intermolar distances was suggested as the key to post treatment stability as these values were believed to represent a position of muscular balance for the patient.⁷

Importance of Arch Form ⁴

- 1) STABILITY: Robert M. Little, Terry R. Wallen, and Richard A. Riedel in 1981 did a study on Stability and relapse of mandibular anterior alignment and concluded that Arch dimensions of width and length typically decreased after retention whereas crowding increased. This occurred despite treatment maintenance of initial intercanine width, treatment expansion, or constriction.
- 2) OCCLUSION: Unless the teeth are aligned in a proper arch form in both upper and lower arches, the occlusion will not be normal. Angle (1907) emphasised this with his concept of Line of Occlusion.
- 3) ESTHETICS: Primary reason for the patient to take treatment. Teeth arranged in proper arch form, will improve smile value as proposed by Sarver (2003).

Basic Types of Dental Arch Form ⁴

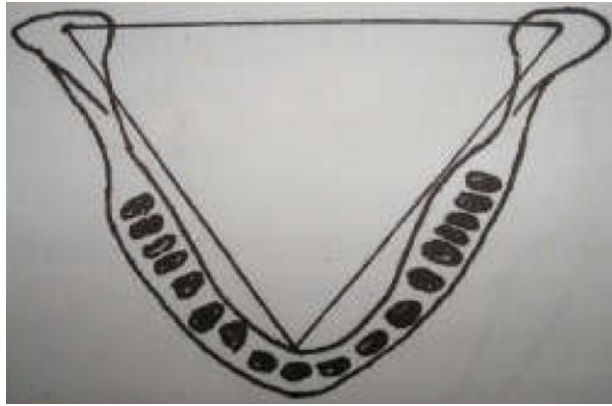
Majority of them fall into one of the following types:

- (1) Parabolic: It is shaped like a parabola, with an anterior curve and slightly diverging posterior legs.
- (2) Hyperbolic: It is shaped like a hyperbola, with a flatter anterior curve and markedly diverging posterior legs.
- (3) Ellipsoidal: It is shaped like an ellipse with a curve anterior segment and slightly converging posterior legs.
- (4) Square: It has a flat anterior segment and relatively parallel posterior legs.
- (5) Omega: It has a curved anterior segment and posterior legs that converge then diverge

Different Concept of Arch Form

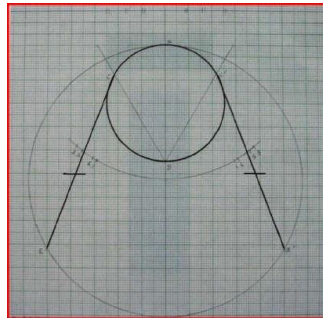
Bonwill's concept ²⁸

Bonwill developed certain postulates for artificial dentures in 1885¹⁵. He noted the tripod shape of the mandible is formed by an equilateral triangle, with its base extending from condyle to condyle and the sides extending from each condyle to the midline of the central incisors. Length of each side is approximately 4 inches. He stated that this triangle existed for the proper functioning of the teeth. Importantly, he noted that the bicuspid and molars formed a straight line from the cuspids to the condyles.



Bonwill Hawley concept

Hawley in 1905, modified Bonwill's concept^{15,28}. Hawley employed some of Bonwill's principles in proposing a geometric method for constructing the ideal arch form. He recommended that the combined widths of the six anterior teeth serve as the radius of a circle and the teeth be placed on that circle. From this circle he constructed an equilateral triangle with the base representing the intercondylar width. It was proposed that the bicuspids and molars should be aligned along these extended straight lines.



The radius of each arch varied depending on size of teeth, so the arch dimensions differed as a function of tooth size but the arch form was constant. In his definition, arch form was determined by the inter second-premolar distance and the patient's original arch form was not considered. For many years, Bonwill-Hawley arch form dominated orthodontic thinking and was the arch wire form most commonly supplied by orthodontic manufacturer.

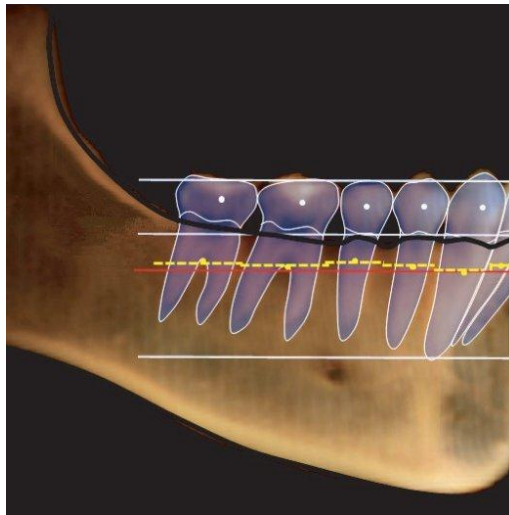
Brader arch form ^{2,30}

Brader in 1972, presented a mathematical model of dental arch form at the annual session of A.A.O for which he won Milo Hellman Research Award Of Special Merit. He proposed that the arch form was a trifocal ellipse, which was based on the findings of Proffit, Norton & Winders. Brader recommended an arch guide with five arch forms. The selection of the proper arch form was based on arch width at the second molars as measured at the buccal and lingual surface.

The maxillary arch form was selected one size larger than mandibular arch form. Therefore Brader hypothesized the arch form as a Trifocal Ellipse, $PR=C$ Where, P = Pressure, R = Radius of curvature of ellipse curve at the pressure site, C =Mathematical Constant, thus the equation expressed the most fundamental association between forces and shape and revealed an inverse relation between force and curvature.

Apical Base Concept

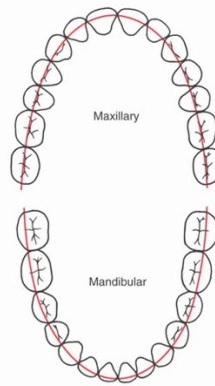
It was proposed by Lundstorm. He highlighted the need to consider the apical base when determining the arch form for the patient.⁴ “Orthodontic experiments showed that a normal occlusion attained by mechanical treatment is not necessarily accompanied by a development of apical base in harmony with the position of the teeth, with the result that the occlusion cannot be maintained.” Occlusion doesn’t control form and amount of apical base development but apical base is capable of affecting the dental occlusion”



Angle’s Line of Occlusion⁶

Angle’s line of occlusion Angle in 1906, described the Line of Occlusion as “The line of greatest normal occlusal contact”. The line of occlusion is a smooth curve passing through the central fossa of each upper molar and across the cingulum of the upper canine and incisor teeth. The same line runs along the buccal cusps and incisal edges of the lower teeth, thus specifying the occlusal as well as interarch relationships once the molar position is established. In 1907, he redescribed it as the line with which in form and in position according to type, the teeth must be in harmony if in normal occlusion⁹. The form of this line was said to resemble a parabolic curve but one that varied greatly due to race, type, temperament, etc. of the individual. Because of these variables, Angle did not consider the Bonwill-Hawley arch form to be useful for anything more than a general approximation of the true line of occlusion. In describing the first order bends needed in the arch form for proper tooth positioning, Angle objected particularly to the straight line proposed from cuspid to third molar. Angle stated

that a straight line existed from the cuspid to the mesio-buccal cusp of the first molar, however, there was a natural curvature needed in the molar region (Edward Angel, 1907).⁶



Catenary Arch Form

Concept first proposed by David Musich & James Ackerman (1973). To measure the arch perimeter, they used an instrument that was a modified Boley Guage with a chain incorporated in it – CATANOMETER²² Schulhoff (1997) used the same concept to describe the lower arch. Catenary curve is the shape that the loop of a chain would take if it were suspended from 2 hooks. Shape of the curve depends on the length of the chain and the distance between the hooks³. When the width across the first molars is used to establish the posterior attachments, a catenary curve fits the dental arch form nicely for most individuals. Preformed arch wires based on average intermolar dimensions. Bruide & Lilley¹⁷ found that the shape of basic bony arch at 9.5 weeks I.U, was catenary design. Catenary curve was made popular by work of McConail & Scher, who felt that from an engineering and biological point of view, the catenary curve was the simplest curve possible and could be easily explained mathematically

MBT arch form²¹

Felton (1987) evaluated a wide range of manufactured arch wires from orthodontic companies and found that the arch forms fell into tapered, ovoid or square groups (first classified by Chuck in 1932). McLaughlin & Bennet (2001) have classified arch forms as tapered, square and ovoid. When superimposed, the three shapes vary mainly in intercanine and inter-first premolar width, giving a range of approximately 6 mm in this area.

Tapered arch form

This arch form has the narrowest inter-canine width and is useful early in treatment for patients with narrow, tapered arch forms. It is particularly

important to use this form for patients with narrow arch forms, and especially in cases with gingival recession in the canine and premolar regions (most frequently seen in adult cases). The tapered arch form is often used in combination with inverted canine brackets for these patients. Cases undergoing single arch treatment often require the use of the tapered arch form. In this way, no expansion of the treated arch occurs, relative to the untreated arch. The posterior part of this arch form can easily be modified to match the inter-molar width of the patient.

Square arch form

This arch form is indicated from the start of treatment in cases with broad arch forms. It is also helpful, at least in the first part of treatment, for cases that require buccal uprighting of the lower posterior segments and expansion of the upper arch. After overexpansion has been achieved, it may be beneficial to change to the ovoid arch form in the later stages of treatment. The square arch form is useful to maintain expansion in upper arches after rapid maxillary expansion.

Ovoid arch form

Over the past 15 years, this has been the authors' preferred arch form for most of their cases. Good reliable arch form for a majority of the cases. Advisable to stock wires in ovoid shape, which then can be altered depending on the case. The combined use of this arch forms with appropriate finishing, settling, and retention procedures has resulted in a majority of cases with good stability, and minimal amounts of posttreatment relapse. However, the recent research indicates that a greater number of tapered arch forms should also be used. It is used in cases with broad arches and those who require buccal uprighting lower posterior segments and expansion of the upper arch. The square arch form is useful to maintain expansion in upper-arch after rapid expansion.

Arch Form in Lingual Orthodontics

Due to the lingual morphology of the teeth, a straight wire cannot be engaged lingually. The arch wire form is changed accordingly. The wires used here are "Mushroom Shaped", with an offset present between canine and premolar. During sliding mechanics, there is a transverse bowing of the arch leading to distortion of the arch form. To prevent posterior legs of the archwire are bowed outward to compensate for the transverse bowing of the arch. Andreiko ³ (1994) asserted that shape of the mandible should dictate the arch form, with the teeth theoretically aligned and contained within the limits of mandibular bone. The arch forms are derived from the skeletal and dental anatomy and are therefore designed to be closer to an anatomic ideal than a mathematical ideal. Previous arch wire shapes had their in the concept of an ideal arch form; anatomy probably was not given enough consideration in design.

The appeal of the newer approach includes the following.

1. Arch forms are derived from the skeletal and dental anatomy and therefore are designed to be closer to an anatomic ideal than a mathematical ideal.

2. Individualized treatment is simplified.
3. This works by scanning models of the patient's dentition to a resolution of 50 μm or 0.002 inch. With a three-dimensional control interface, the clinician has the capability of specifying exactly how each tooth is oriented as it moves to the desired position and can design arch shape as desired, within the parameters of the scanned limits of the buccal and lingual cortical plates.
4. Once the patient's customized occlusal scheme is finalized, the data from the setup then is drawn on by the CAD-CAM machinery to cut each bracket to individual specifications for that patient, and the arch wires also are manufactured to the specifications set by the clinician.

He concluded that it was impossible to represent one ideal arch form. However, in the literature, no study has reported reference points to describe the dental arch from the lingual perspective. The introduction of straight wire concepts to the lingual technique has led clinicians to pose the important questions of which form should be used in setting up indirect bonding and according to which criteria²⁰ (Luca Lombardo et al., 2010). After computerized digitizing and the use of a mathematical function called a polynomial of the fourth degree, they determined that there is no particular arch form predominated in any of the three samples. They therefore stated that customizing arch forms appeared to be necessary in many cases to obtain optimum a long-term stability, because of the great variability in arch form observed in the study. The overall result of these clinical observations and research papers is that, because of the extensive variations in human arch form, there does not seem to be any single arch form that can be used in all orthodontic cases. Also, when the patients original arch form is modified, there is a strong tendency (in approximately 70% of cases) for the arch form to return to its original shape after appliances are removed.

Rocky mountain data system

Computer derived formula relies upon measurements taken from inter molar width, inter cuspid width and arch depth as measured from the facial surface of the incisors to the distal surface of the terminal molar. This allows computer to be programmed with Cartesian X & Y co-ordinates that are necessary for arch computation. Facial type is also considered but arch design is applicable only to the lower arch⁴.

Ricketts pentamorphic arch forms²⁴

At least ten factors needed to be considered in the research of arch form. This included arch correlation, the consideration of size, arch length, where the arch was to be measured, contact details and final determination of form at the bracket location. Originally 12 arch forms were identified from different studies. These were narrowed to 9 by computer analysis. Studies of other normal and stable treated patients resulted in elimination of all but 5 forms. Rework with normal occlusions led to precise prescription for these forms. Verification of the arch form was then carried out. With the kind of agreement offered, it became practical to prefabricate and heat treat the arches for third stage management. These were labelled Pentamorphic Arches and were to be selected by technical method are narrow ovoid, ovoid, normal ideal, narrow tapered and tapered.

Discussion

The dental arch, an important element in orthodontics, is a fundamental principle in orthodontic planning and therapy (Richard A. Riedel, 1960)²⁵. A dental arch form is initially established by the configuration of the supporting bone, and following eruption of the teeth, by the circumoral musculature and intraoral functional forces (Rudolph L. Hanau, 1917).²⁸ The size and shape of the arches will have considerable implications in orthodontic diagnosis and treatment planning, affecting the space available, dental aesthetics, and stability of the dentition (Robert H.W. Strang, 1946). Arch dimensions change with growth. It is therefore necessary to distinguish changes induced by appliance therapy from those that occur from natural growth. Moorrees (Baluta and Lavelle, 1987) has pointed out that considerable individual variation in arch form will occur with normal growth, with a general tendency toward an increase in the intermolar width during the changeover from the deciduous to the permanent dentition (Robert H.W. Strang, 1946)²⁶. It is apparent that changes in arch width vary between males and females and that more growth in width occurs in the upper than the lower arch; this growth occurs mainly between the ages of 7 and 12 years of age and is approximately 2 mm in the lower arch and 3 mm in the upper. After the age of 12, growth in arch width is seen only in males (Knott, 1972). Changes in the size and shape of skeletodental-craniofacial complexes do not cease with the attainment of biologic maturity (Efisio Defraia et al., 2006). Even controlling for age progressive adult changes due to dental disease and imbalances in bone dynamics, it is still evident that the several decades of adult life are not an interval of no growth. Instead, even though the rates of change are much slower and directions of growth (or "aging") may be different from those in children and adolescents, changes are readily discernible, especially over the long term. Arch width continues to increase to a lesser extent in the third and fourth decades, but this is associated with arch length shortening (Efisio Defraia et al., 2006)¹². Preservation of dental arch shape and maintenance of dentition during growth is an indicator of the equilibrium of teeth between tongue and circumoral muscle forces (Allen C. Brader, 1972)². The intermolar width tends to return to the pre treatment value during the post retention period in most of the studies. These reported changes in intercanine and intermolar width are greater in the mandibular arch than the maxillary arch. Although most of the arch changes are seen before age 30, mandibular anterior crowding continues into the fifth decade. Many studies in the literature document analyses of the shape of the dental arches, with different methodologies, of similar samples of healthy subjects with normal occlusion to obtain clinical data pertinent to the labial edgewise technique. All of these authors concluded that it was impossible to represent one ideal arch form. However, in the literature, no study has reported reference points to describe the dental arch from the lingual perspective. The introduction of straight-wire concepts to the lingual technique has led clinicians to pose the important questions of which form should be used in setting up indirect bonding and according to which criteria (Luca Lombardo et al., 2010)²⁰. After computerized digitizing and the use of a mathematical function called a polynomial of the fourth degree, they determined that no particular arch form predominated in any of the three samples. They therefore stated that customizing arch forms appeared to be necessary in many cases to obtain optimum long-term stability, because of the great variability in arch form observed in the study. The

overall result of these clinical observations and research papers is that, because of the extensive variations in human arch form, there does not seem to be any single arch form that can be used in all orthodontic cases. Also, when the patients original arch form is modified, there is a strong tendency (in approximately 70% of cases) for the arch form to return to its original shape after appliances are removed.

Conclusion

The search for a universal ideal arch form has been one of the most persistent but exclusive tasks that orthodontic researchers have pursued. Current literature illustrates many divergent views on the shape of arch form. It is now generally believed that the arch shape is determined by an interplay between genetic and many varied environmental factors such as pressure from soft tissues; shape and position of jaws; alteration in eruptive mechanism and morphology of teeth. The basic principle of arch form in orthodontic treatment is that within reason, the patients original arch form should be preserved. These variations in arch form, however, are not reflected in the preformed arch wires presently available and it is important to keep in mind during orthodontic treatment that if they are used, their shape should be considered a starting point for the adjustments necessary for proper individualization. Clinicians should therefore be cautious when treating individuals to a mathematically derived ideal. Because of these complex problems, and relatively low knowledge of dental arches, as of today, there is no universally accepted ideal arch form. The irony of wisdom is that, the more we know about a particular subject, the more our ignorance unfolds and the goal seems far ahead.

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