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RESEARCH ARTICLE

ARCH FORM

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ABSTRACT

Arch form is highly individualized. During orthodontic treatment patients original arch form should not be affect the equilibrium between bone, dental structure and muscular structure Dental arch width and form are important factors for determining the success and stability of orthodontic treatment. One goal of orthodontic treatment is to create a dental arch form that establishes a stable relationship with the underlying basal bone.

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INTRODUCTION

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. (Alexander Sved, 1952) Today, however, many normal variations are emphasized more than the specific type of arch forms. Recent studies nullify the existence of a single ideal arch- form template, indicating that dental arch forms are highly individual, and defining a single generalized shape and using variations of it should be avoided. (Allen C. Brader, 1972) 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) It is well established that increase in dental arch length and width during orthodontic treatment tend to return toward pretreatment 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 pretreatment 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. (Anwar and Fida, 2010)

Different concepts of arch form

Bonwill's concept

Bonwill developed certain postulates for artificial dentures in 1885. 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

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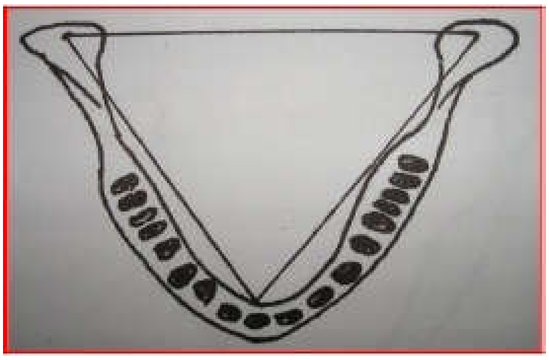
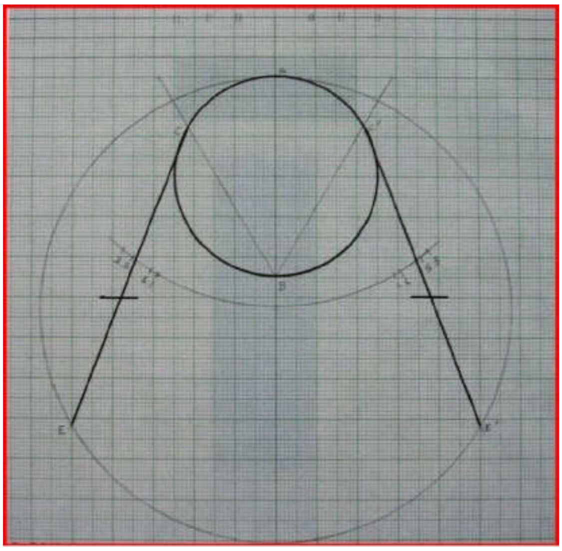
approximately 4 inches. He stated that this triangle existed for the proper functioning of the teeth. Importantly, he noted that the bicuspids and molars formed a straight line from the cuspids to the condyles.



Bonwill hawley concept

Hawley in 1905, modified Bonwill's concept. 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 manufacturers.

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 occlusion[8]. 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).

Apical base concept

In 1925, Lundstrom proposed a new term "apical base" to describe the limits of expansion of the dental arch and wrote extensively on this topic. He highlighted the need to consider the apical base when determining the arch form for the patient. According to the "apical base" theory, the size and shape of the supporting bone are largely under genetic control, and there is a limit to expansion of a dental arch.

Catenary arch form

In 1949, MacConaill stated that, in considering the line of occlusion, it would be impossible for an ellipse and a parabola to meet one another at every point. He concluded that the ellipse parabola description of the two dental arches, although elegant, had no immediate relation to function. He stated that a certain simple and well known curve, the catenary curve, fit so many cases with exactness that it could be taken as the "ideal curve" of common occlusions. The catenary curve is a geometric curve produced by a chain of many links (of appropriate length) suspended from two points of varying width (for example width of the most distal molars in the arch form) but otherwise allowed to hang freely and has been conveniently used as a reference standard (Andreiko, 1994). In 1957, Scott also supported the concept of the catenary curve as the shape of the human arch based on the developmental anatomy of the dental arches and surrounding anatomic structures. David Musich & James Ackerman (1973), supported the concept of the catenary curve as the ideal arch form and suggested the use of the Catenometer, that was a modified Boley Guage with a chain incorporated in it, as a reliable device for construction of arch perimeter.

Brader arch form

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 gingival 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.

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 arch.

Ricketts pentamorphic arch forms

Atleast ten factors needed to be taken into account 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 labeled Pentamorphic^{TM} Arches and were to be selected by technical method are narrow ovoid, ovoid, normal ideal, narrow tapered and tapered

MBT arch form

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 inter-canine 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 post-treatment 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 this posterior legs of the archwire are bowed outward to compensate for the transverse bowing of the arch. Andreiko (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.

DISCUSSION

The dental arch, an important element in orthodontics, is a fundamental principle in orthodontic planning and therapy

(Richard A. Riedel, 1960). 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). 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). 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). Arch shape affects both the functional and the esthetics of the occlusion. 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).

Although the forces are not equivalent, the general effect of intermittent forces by the tongue and resting forces of the cheeks are likely to result in the final positioning of the teeth. The objective of orthodontic treatment might reasonably be to limit encroachment on the space occupied by the lips and cheeks with redistribution of the dentition in space, utilizing space created in one arch for the accommodation of teeth from the opponent arch (Robert H.W. Strang, 1946). Early investigators studied arch form with the hope of improving their prosthetic appliances. As orthodontics advanced as a speciality, Angle and others recognized the importance of arch form in the proper planning of treatment. Thus, study models were early introduced as a vital diagnostic aid. Every practicing orthodontist today is aware of the importance of considering arch form in the attainment of a functional orthodontic correction (Interlandi, 1998). From these representations, diagrams were developed on the basis of measurements of dental arch components that would act as a guide during orthodontic treatment, because the use of a customized diagram would provide archwires with standardized forms and dimensions. However, the use of diagrams describing an average or ideal dental arch form was counter indicated when some authors observed that the dental arch curve was represented or defined not only by a geometric shape, but also by several configurations. Most studies evaluating arch form directly have been cross-sectional and have tested methods to describe and find a specific arch form. Early methods (Hawley,1905; William, 1917) were subjective and have been replaced by methods using mathematical equations such as 2^{nd} to 8^{th} polynomials (Lu,1966; Pepe,1975; Richards *et al*, 1990), cubic splines (BeGole,1980), parabola (Jones and Richmond,1989), ellipses (Currier, 1969), catenary curves (Pepe, 1975), beta function (Braun *et al*, 1998), and conic sections (Sampson, 1981). Rudge (1981) has given a thorough review on the subject. Limitations in techniques to quantify arch form changes as stated by Sampson (1981) and De La Cruz *et al*. (1995), could explain why methods for arch form determination have rarely been used in longitudinal investigation. Felton *et al*. (1987) who used 4^{th} degree polynomials to dental arch form found poor post treatment stability in 70% of the non extraction sample but did not report the method applied to assess the arch form. De La Cruz *et al* (1995) adopted conic sections, a method described by Sampson to assess different arch forms (circles, ellipses, parabolas, hyperbolas). They found that dental arch forms in subjects with class I and class II malocclusion treated with extraction tended to return to their pre-treatment form in the post treatment form. Recently Davis and BeGole (1998) verified, that with the use of cubic spline function, that changes that occur during treatment tend to relapse during post treatment (Jan Henrikson *et al*., 2001).

Because a ‘‘straight’’ arch form has not previously been described from a lingual perspective and this is fundamentally important in orthodontic treatment planning, in this study it is described with an objective, standardized, and reproducible methodology: a natural and anatomic arch form obtained from subjects with normal occlusion. This can be used, with other criteria, in the construction of personalized setups for the lingual straight-wire technique. Most researchers have found greater changes in the male components of their samples. Because the supporting bones of the mid face and the mandible do not reach mature size until well into the teens or early twenties, it seems likely that minor occlusal adjustments and changes in tooth position also continue throughout this phase (Efisio Defraia *et al*., 2006). Long-term post treatment stability is an issue of great concern to all orthodontists. Retention after orthodontic treatment has been defined by Moyers (Alexander Sved, 1952) as “the holding of teeth following orthodontic treatment in the treated position for the period of time necessary for the maintenance of the result” or by Riedel as “the holding of teeth in ideal aesthetic and functional position. ”The proposed basis for holding the teeth in their treated position is to: allow for periodontal and gingival reorganization; to minimize changes from growth; to permit neuromuscular adaptation to the corrected tooth position; and to maintain unstable tooth position, if such positioning is required for reasons of compromise or esthetics.

Intercanine width reduction is seen post treatment whether the case was expanded during treatment or not. 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). 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 exlusive 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 from 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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