Journal of Institute of Medicine Nepal
Institute of Medicine, Kathmandu, Nepal

OPEN ACCESS

Original Article

JIOM Nepal. 2023 Aug;45(2):49-53.

Arch Form and Mathematical Ratio in Orthodontics Patients: A Descriptive Cross-sectional Study

Surendra Maharjan, Anjana Rajbhandari, Resina Pradhan, Manju Bajracharya, Pushkar Manandhar, Bashu D Pant

Author(s) affiliation

Department of Orthodontics and Dentofacial Orthopedics, People's Dental College and Hospital, Sorhakhutte, Kathmandu

Corresponding author

Surendra Maharjan, BDS, MDS
maharjan.surendra@gmail.com

ABSTRACT

Introduction

Orthodontic treatment aims to achieve a pleasing and stable occlusion. To attain these, the patient's arch shape should be determined before treatment and maintained during treatment. Many attempts have been made to find out the original arch form, but those procedures have had some difficulties. The aim of this study was to determine the arch form using a comparatively simpler mathematical ratio.

Methods

In this observational, descriptive cross-sectional study, 300 maxillary pretreatment casts from various malocclusion cases were collected. To determine the arch form, the mathematical ratio (CD/CW)/ (MD/MW) was used. Data were collected in Microsoft Excel and analyzed in IBM SPSS for descriptive statistics and one way ANOVA.

Results

Among 300 individuals, 108 (36%) were males and 192 (64%) were females. In 29 (9.67%) males had square, 48 (16%) had oval, and 31 (10.33%) had tapered shaped arch forms, while 54 (18%) females had square, 77 (25.67%) had oval, and 61 (20.33%) had tapered shaped arch forms. The mean values of arch form were significant in both gender and age groups.

Conclusion

The majority of participants had an oval arch form, followed by a tapered and square-shaped arch form.

Keywords
Arch form; mathematical ratio; orthodontic treatment

Submitted
May 7, 2023

Accepted
Jul 30, 2023

INTRODUCTION

The main objective of orthodontic treatment is to obtain esthetic harmony, structural balance and functional efficiency of the maxillomandibular relationship including the dental arches. It is very crucial to maintain the original arch form of the patient from the beginning to the end of the orthodontic treatment.[1,2] Studies have shown that maintaining the pretreatment arch shape until the end of treatment will maintain long term post treatment stability. Thus determination of arch shape is essential in orthodontics.[3,4]

Various methods have been used to determine the proper arch shape. The earliest attempt of measuring the arch length and width was made by Bonwill (1887)[5], later popularized by Hawley (1905) with some modification in it.[6] Brader (1972) presented a mathematical model to determine dental arch form based on a trifocal ellipse that resembles a hen egg in longitudinal section.[7] Braun et al. (1998) developed the beta function, a complex mathematical formula where calculations made on measurements of dental landmarks on orthodontic models into a computer curve fitting program.[8] Noroozi H et al. (2001) used a method measuring four parameters of a dental arch in the canine and second molar regions, and the values obtained were used in the specific equation. This method overcame the complexity of the beta function.[9] Budiman JA (2017) developed even a simpler mathematical ratio for identifying arch form using arch dimension variables.[10]

Methods mentioned earlier to determine the arch form need either the template developed by the researcher or extensive mathematical calculation, which is a more time-consuming and exhausting step for the clinician. Few methods require computers and software programs that require extra qualifications and training.

Thus, the aim of this study was to determine the arch shape of orthodontic patients by using a mathematical method developed by Budiman that will provide orthodontists with an idea for selecting the proper arch wires needed for that particular patient throughout the treatment.

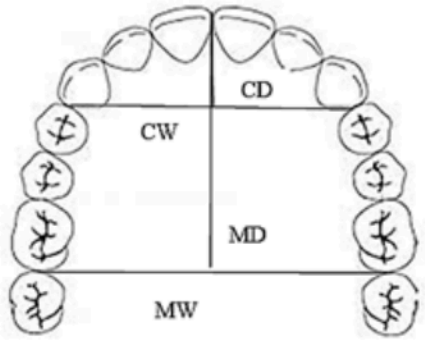

Figure 1. *Measurement variables in printed copy of scanned maxillary cast*

METHODS

This observational, descriptive cross-sectional study was conducted in the Department of Orthodontics, People's Dental College and Hospital, Kathmandu, Nepal, from November 2022 to March 2023. The ethical approval for the study was obtained from the Institutional Review Committee (Reference Number: 1/41, 2079/2080) of People's Dental College and Hospital. The convenience sampling method was used based on inclusion and exclusion criteria. A total of 300 maxillary pretreatment casts from various malocclusion cases were collected. The inclusion criteria for the cases were the patients visiting the orthodontic department of People's Dental College and Hospital for treatment, individuals with all permanent dentition except third molars in the maxillary arch, and malocclusion cases that fall under Angle's Class I, II, and III categories. The exclusion criteria were cases with dental anomalies like hypodontia, supernumerary teeth, conditions like posterior crossbite, retained deciduous teeth, severe crowding, huge midline diastema, severe transverse arch discrepancies, and patients with cleft lip and palate.

The sample size was calculated using the formula N = z2 pq/d2 where z = 1.96 at the 95% confidence interval, p = 0.26 from reference article[11], q = 0.74 and d = 0.05. The sample size was 296. However, in this study, 300 participants were included. A written consent was obtained from the patients

Table 1. *Descriptive analysis of different arch form, n (%)*

Gender	Arch form			Total
	Square	Oval	Tapered	
Male	29 (9.67)	48 (16)	31 (10.33)	108 (36)
Female	54 (18)	77 (25.67)	61 (20.33)	192 (64)
Total	83 (27.67)	125 (41.67)	92 (30.66)	300 (100)

Table 2. *Distribution of different arch form in different age group and gender, n (%)*

	Gender	Arch form			Total
		Square	Oval	Tapered	
≤16 years	Male	9 (10.47)	14 (16.28)	7 (8.14)	30 (34.89)
	Female	14(16.28)	16 (18.60)	26 (30.23)	56 (65.11)
>16 years	Male	20 (9.34)	34 (15.89)	24 (11.21)	78 (36.44)
	Female	40 (18.70)	61 (28.50)	35 (16.36)	136 (63.56)

prior to data collection. Participants' maxillary arch impressions and casts were prepared. All the casts were scanned at a 1200 dpi resolution with teeth touching the glass of the scanner (the brother MFC-L2700DW model). Scanned pictures were then printed without any change in magnification. Measurements were made on those printed copies of the casts. To determine the arch form, the mathematical ratio developed by John A. Budiman was used. Here (CD/CW) and (MD/MW) were used, where CD is canine depth, CW is canine width, MD is molar depth, and MW is molar width (Figure). A ratio less than 45.30% indicates square, 45.30–53.37% indicates oval, and more than 53.37% indicates tapered arch form.

Landmark localization and measurements were done by the principle investigator to avoid interobserver variation. Cohen's Kappa test result was 0.81, indicating higher reliability of the measurements. Data were collected in Microsoft Excel and analyzed in the Statistical Package for Social Sciences version 20 (IBM SPSS). For descriptive statistics, frequency, percentage, mean, and standard deviation were calculated. A one-way ANOVA was used to compare the mean values of different arc forms in different age groups.

RESULTS

Out of 300 individuals, 108 (36%) were males and 192 (64%) were females. Among them, 29 (9.67%) males had a square, 48 (16%) had an oval, and 31 (10.33%) had a tapered-shaped arch form. Similarly, 54 (18%) females had a square, 77 (25.67%) had an oval, and 61 (20.33%) had a tapered-shaped arch form (Table 1).

Among the participants in the 16 years and below age group, the majority of males, 14 (16.28%), had an oval arch form, while 26 (30.23%) females had a tapered arch form. However, in the above 16-year-old group, the majority of both males (34, or 15.89%) and females (61, or 28.50%) had oval arch forms (Table 2).

In square and tapering arch forms, males had higher mean values of mathematical ratios of [(CD/CW)/(MD/MW)] in both age groups, whereas in oval arch forms, females had higher mean values. Additionally, the difference in mean values in both the gender and age groups were statistically significant (Table 3).

DISCUSSION

The prime finding of this study showed that the majority had oval-shaped arches, followed by tapered and square-shaped arch forms. The pattern was similar for both genders. Our result was similar to that of Khatri et al.[12] ,Doddamani et.al.[13] and Shrestha R.[11]

According to Stanley J. Nelson, root completion of the maxillary second permanent molar occurred by 16 years of age.[14] Based on this fact, participants were divided into two age groups: up to 16 years and above 16 years, to determine any differences in arch form after the complete formation of these

Table 3. *Mathematical ratio [(CD/CW)/(MD/MW)] of different arch forms in different age group and gender, mean±SD*

	Gender	Mathematical ratio [(CD/CW)/(MD/MW)] (mean±SD)			p-value
		Square arch form	Oval arch form	Tapered arch form	
≤16 years	Male	42.16±2.72	47.87±2.36	58.64±1.55	p<0.001*
	Female	41.22±1.45	50.13±1.96	57.75±1.85	p<0.001*
>16 years	Male	42.97±1.61	48.42±2.17	58.86±5.67	p<0.001*
	Female	40.28±3.13	49.50±2.31	56.20±2.68	p<0.001*

molars. It was observed that in males, the oval arch form predominates in both age groups, whereas in female, the tapered arch form predominate in below 16 years group and the oval arch form predominates in the above 16 years group. A study by Paulino et al. also revealed that no significant changes occurred in arch width with transition of age.[15] In this study, mean values for oval arch forms were higher in females in both age groups whereas those for square and tapering arch forms were higher in males. The mean values in the age and gender groups were statistically significant. This outcome was more in line with Shrestha et al.'s study.[16]

Orthodontists should maintain patient arch form throughout the treatment as alteration in arch form could influence the esthetic, function and stability of the occlusion. It was observed that significant increase in arch width occurred with the arbitrarily chosen use of preformed archwires.[17] Thus appropriate archwire should be selected during treatment but many orthodontists neglect this fact and determine arch form just by visual examination especially during use of NiTi wire. It will be time consuming to correct those altered arch forms with customized stainless steel arch wire in later stage of treatment.[18,19] Various methods have been developed to determine arch form.[5-10] Among them, this mathematical method was found simple and easy to use; there was neither a need for a specific template nor a need to use complex formulas. It gives an idea of arch form from measurements in the molar and canine areas.

In this research, it was observed that cases with retroclined incisors and small sized lateral incisors had a square arch form while cases with proclined incisors had a tapered arch form. Missing premolars decrease the molar depth resulting in an arch that is more square shaped. In some cases, it was also noted that the anterior portion of the arch outline differed from the general arch form, such that the overall arch form showed an oval shape but the anterior portion seemed tapered in nature. It might be due to differences in tooth size and position in the anterior and posterior regions.

Some limitations of this method were difficulty in point location in erupting or rotated canines and second molars, in cases with deciduous canines, missing or ectopic erupted teeth, and in arches with improper tooth contact. Furthermore, this research was carried out on individuals with different types of malocclusions, yet associations between particular types of arch forms and specific malocclusions were not examined here. Likewise, the relationship between face type and arch form and the prevalence of various arch forms in different ethnic groups were not studied. Thus, an expansion of this study in these areas is also recommended.

CONCLUSION

Most of the individuals had oval arch forms followed by tapered and square shaped arch forms. The majority of young females showed tapered arch forms while young and adult males exhibit oval arch forms. The mathematical ratio (CD/CW)/(MD/MW) can be used to determine arch form.

FINANCIAL SUPPORT

The author(s) did not receive any financial support for the research and/or publication of this article.

CONFLICT OF INTEREST

The author(s) declare that they do not have any conflicts of interest with respect to the research, authorship, and/or publication of this article.

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