

ORIGINAL ARTICLE

## Bolton tooth size ratio and its relation with arch widths, arch length and arch perimeter: A cone beam computed tomography (CBCT) study

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### Abstract

**Objective.** The prime aim of the study was to measure and compare the 3D CBCT Bolton tooth size ratio in relation to the upper and lower arch widths, arch length and arch perimeter. **Materials and methods.** The data source was CBCT high volumetric data from the archives. Tooth size, arch widths, arch length and arch perimeter were measured in maxilla and mandibular arches. The independent *t*-test and ANOVA were used for statistical analyses. **Results.** The female Bolton anterior ratio (BAR) (78.373) and Bolton overall ratio (BOR) (93.231) show a greater tooth size ratio in comparison to male BAR (77.162) and BOR (93.124), respectively. However, no significant difference was found in the sexual comparison of all the measurements. Tooth size ratio in arch width groups also showed no significant difference. Significant discrepancies in the arch length ( $p < 0.05$ ) groups and overall ratio and in the arch perimeter groups ( $p < 0.05$  and  $p < 0.01$ ) and anterior ratio were revealed. **Conclusions.** Tooth size ratios during orthodontic treatment for different arch length and arch perimeter groups need to be evaluated carefully.

**Key Words:** 3D CBCT, tooth size ratio, arch width, arch length, arch perimeters

### Introduction

The Bolton Index is one of the most useful calculations for precise orthodontic diagnosis. However, at times, this calculation is not applied because of its long and time-consuming procedure compared with digital methods. Measurements of tooth-size and the later calculation of the Bolton Index that would customarily be undertaken with 2D digital study models can now accurately be done on three-dimensional study models obtained from a CBCT [1].

A good equilibrium should be present between the mesio-distal tooth size of the maxillary and mandibular arches to guarantee settlement in normal occlusion with horizontal and vertical overlap at the completion of orthodontic treatment [2–4].

Tooth size discrepancy in the dental arches such as the peg shaped lateral teeth need space management for the final restoration of normal occlusion. Larger discrepancy in the tooth size can also affect the

extraction choice in the orthodontic treatment final stage [5–7].

Tooth size ratio determination is an inter-maxillary analysis planned for the reason of localizing dissimilarity in tooth size for anterior and overall discrepancy and by weigh against it with normal standard, the defective arch is determined. To accomplish good occlusion with proper inter-digitations, vertical and horizontal relation, there must be a specific relationship between the mesio-distal tooth dimensions to seat in good occlusion. Discrepancy in the tooth size needs to be measured in the orthodontic practice before starting the orthodontic treatment [8].

For the management of the space and crowding troubles in the field of dentistry, tooth size is of enormous significance to general dentists, pedodontists and orthodontists [9].

In the subject of orthodontics, the tooth size discrepancy in relation to the treatment part takes enormous discussion in the literature. If tooth size and arch dimension is accurately predicted before the

occurrence of malocclusion, then the estimation can be used to prevent or reduce the severity of many malocclusions either by serial extraction, guidance of eruption, space maintenance, space gaining or periodic observation of the patient for orthodontic treatment [7,10–20].

CBCT allows us to determine tooth size and arch dimension as quickly, reliably, accurately and reproducibly matched with dimensions (measurement) obtained using the digital method on digitalized plaster models. There are no clinical differences between measurements using the CBCT method and those using the digital method (2D) [21].

To date, in the literature only one study has been conducted on 3D CBCT-based calculations of anterior and overall Bolton ratios in a Turkey population with a smaller sample size [22], whereas no study has been conducted on the tooth size ratio in kin to arch widths, arch length and arch perimeters through 3D CBCT measurement. The prime goals of the study were to:

- (1) determinate the sexual dimorphism in anterior and overall tooth size ratio through 3D CBCT acquisitions; and
- (2) suggest the relation and effect on Bolton tooth size ratio by the arch width, arch length and arch perimeters.

## Materials and methods

### Subjects

All participants provide their written informed consent prior to CBCT and this study was approved by the Ethical Committee of the Hospital Universiti Sains Malaysia (HUSM), which complies with the Declaration of Helsinki. This study was designed

and conducted according to the guidelines of Strengthening the Reporting of Observational studies in Epidemiology (STROBE) and we applied the STROBE checklist in the preparation of this manuscript [23].

The data source was CBCT high volumetric data from the archives of the School of Dental Sciences, HUSM. Tooth size, arch length, arch perimeter, inter-canine, inter-first premolar, inter-second premolar and inter-molar arch widths were measured and recorded in 53 3D CBCT high volumetric data (32 male and 21 female, mean age = 25.81), both in maxilla and mandibular arches. All measurements were obtained via CBCT Planmeca Romexis software (Figure 1).

### Inclusion criteria

High quality CBCT volumetric data and using full dentition in both maxilla and mandibular arches excluding the third molars. The ethnicity (Malay) of the subject was determined from the record.

### Exclusion criteria

CBCT data, subjects with sever crowding, excessive spacing, periodontal disease, retained deciduous teeth, fixed orthodontic appliance, inter-proximal caries or restoration, missing or supernumerary teeth, abnormal size or morphology of teeth, tooth wear to the extent of impairment of the contact point, damage or extorted CBCT 3D acquisitions and any radiographic evidence of pathology within the maxilla or mandible were excluded.

The tooth size, arch length, arch perimeter, arch widths were measured through CBCT 3D acquisition as in Figure 2.

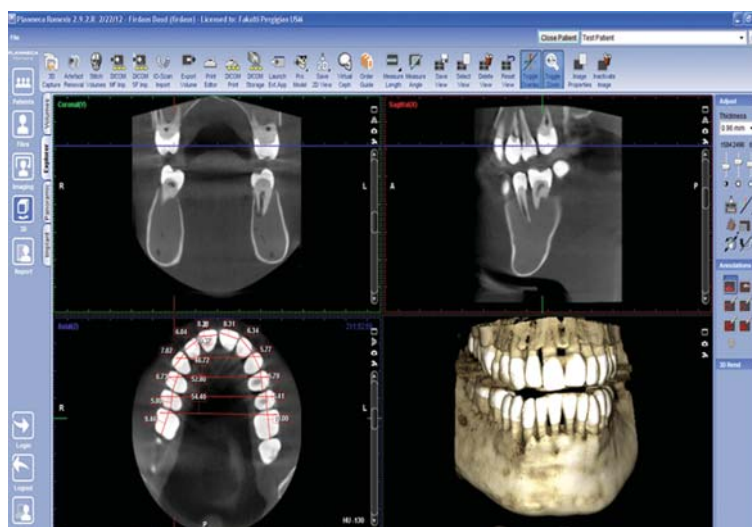


Figure 1. CBCT measurement via Planmeca Romexis software.

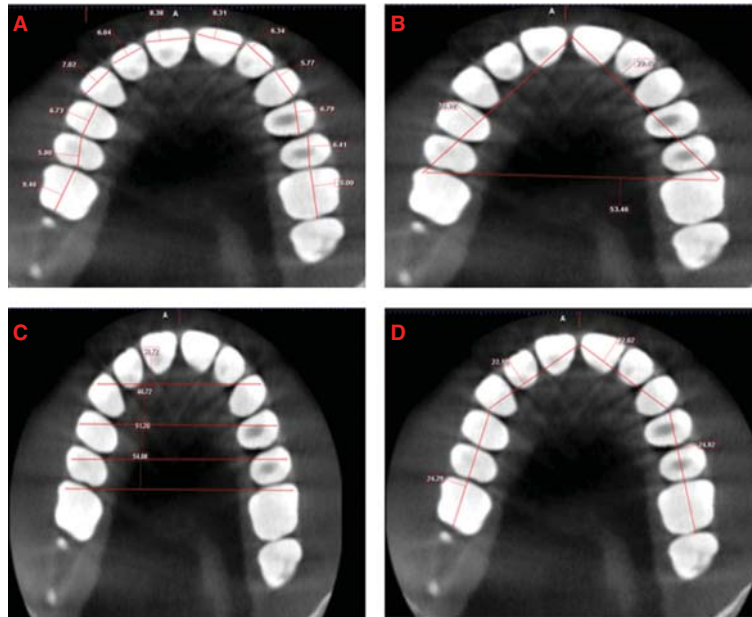


Figure 2. CBCT measurements of (A) Tooth size, (B) Arch width, (C) Arch length and (D) Arch perimeter.

#### *Tooth size measurement*

Tooth size measurements were carried out with a reading accuracy of 0.001 mm. Mesio distal width of the tooth was measured from anatomical contact of one tooth occlusal side (Figure 2A) [24]. Tooth size was analysed for the Bolton anterior ratio (BAR) and Bolton overall ratio (BOR) with the application of the subsequent principle [6].

$$\text{BOR} = \frac{\text{sum of the mandibular 6 to 6}}{\text{sum of the maxillary 6 to 6}} \times 100$$

$$\text{BAR} = \frac{\text{sum of the mandibular 3 to 3}}{\text{sum of the maxillary 3 to 3}} \times 100$$

#### *Arch width measurements*

Arch widths for all the maxillary and mandibular groups were obtained as shown in Figure 2C.

#### *Inter-canine widths of maxillary and mandibular arches*

The point denoted from the cusp tip of one side to the opposing side cusp tip, for the wear canines the mid-point of the wear facets were manifest as an orientation in the upper and lower arch.

#### *Inter 1<sup>st</sup> premolar and 2<sup>nd</sup> premolar widths of maxillary and mandibular arches*

Points were marked on the 1<sup>st</sup> and 2<sup>nd</sup> premolar were marked from the buccal cusp tip to the buccal cusp tip of the contralateral side.

#### *Inter-molar widths of maxillary and mandibular arches*

Linear distance obtained from mesio-bucal cusp tip of right side to the left side.

#### *Arch length*

A transverse line connecting between three points, as from the mesio-bucal cusp tip to the mesio-bucal cusp tip of the opposite side of first permanent molar and the line then protracted from both side anteriorly to the centre point between the central incisors for both the maxillary and mandibular arch (Figure 2B).

#### *Arch perimeter*

The sum of fragmental lines from the right and left side of the arch (these segments are starting from the distal contact of the molar to the mesial contact point of the canine and after here to the contact point of the central incisors) (Figure 2D).

The subjects were further grouped as follows:

- (1) *Arch widths group* (Narrow, Average, Broad);
- (2) *Arch length group* (Increased, Average, Decrease); and
- (3) *Arch perimeters group* (Smaller, Medium, Larger).

This grouping has been done based on the data values of Mean  $\pm$  2 SD,  $>$  2 SD and  $<$  2 SD grouped in average/medium group, broad/increased/larger group and narrow/decrease/smaller group, respectively.

#### *Statistical analysis*

After data collection, data were analysed through SPSS Statistics Version 20.0 with a probability level

of 0.05 measured to be statistically significant. For the male and female BAR and BOR, the student *t*-test was applied to decide statistically significant significance. For the observation of any significant difference between the BAR and BOR in relation to arch width, arch perimeter and arch length groups, analysis of variance (ANOVA) was used.

## Results

The gender and dental arches demographic groups of the subjects in our study are shown in Table I. Tooth size, arch widths, arch length and arch perimeter were measured in maxilla and mandibular arches. The student *t*-test and ANOVA were used for statistical analyses. The female BAR (78.373) and BOR (93.231) shows a greater tooth size ratio in comparison to male BAR (77.162) and BOR (93.124), respectively. However, no significant difference was found in the sexual comparison of all the measurements for the tooth size discrepancy (Table II).

Figure 3 shows the BAR and BOR in relation to the maxillary arch width in inter-canine, inter 1<sup>st</sup> premolar, inter 2<sup>nd</sup> premolar and inter-molar region. Our results showed that no statistically significant differences were found among the narrow, average and broad maxillary arches. The BOR and BAR in relation to the mandibular arch width groups also showed no significant differences (Figure 4).

Figure 5 summarizes the BAR and BOR for those with maxilla and mandibular arch groups (excessive arch length, average arch length, decreased arch length). Our result demonstrates that there were statistically significant differences between the mandibular excessive arch length and average arch length in relation to BOR ( $p = 0.02$ ). Figure 6 summarizes the BAR and BOR precisely to the arch perimeter of the maxilla and mandible. There were statistically significant differences observed among the various

Table I. Gender and dental arches demographic groups of the subjects.

		Number of subjects	Total
Sex	Male	32	53
	Female	21	
Arch width	Narrow	17	53
	Average	17	
	Broad	19	
Arch length	Excessive	16	53
	Average	17	
	Decreased	20	
Arch perimeters	Small	18	53
	Medium	15	
	Large	20	

Table II. Bolton anterior and overall ratio in relation to sexual dimorphism.

	Sex	Mean	SD	SE	95% CI		<i>p</i>
					Lower	Upper	
Anterior ratio	Male	77.162	4.001	0.707	3.891	1.469	0.369
	Female	78.373	5.727	1.250			
Overall ratio	Male	93.124	2.691	0.476	2.060	1.846	0.913
	Female	93.231	4.402	0.961			

CI, Confidence Interval; SD, Standard deviation; SE, Standard error.

arch perimeter groups in relation to the BAR. There were statistically significant differences between the maxillary small vs medium and small vs large arch perimeter in relation to BAR ( $p = 0.02$  and  $p = 0.002$ , respectively). In relation to BOR, no significant differences were observed.

## Discussion

Tooth size discrepancy is of extreme importance at the finishing stage of orthodontic treatment. The orthodontist should be aware of the tooth size discrepancy [2,3]. For the orthodontic patient with significant tooth size discrepancy, it is impossible to achieve ideal occlusion with proper inter digitation.

The 3D models gained from the CBCT are as precise and replicable as the digital models achieved from the plaster study casts for calculating the tooth size and discrepancies. The variances present among both approaches were clinically satisfactory [1]. Several companies, including GeoDigm (GeoDigm Corp., Chanhassen, MN) and OrthoCAD (CADENT, Ind., Fairview, NJ), have dramatically refined this approach. These advances have made the capture of scanned images a commercially viable enterprise and OrthoCAD utilizes the computer-aided design technology (CAD) for generation of its digital study models. As computer software technology continues to progress, advances may provide for a single piece of imaging equipment, such as a cone beam computed tomography, to provide the full complement of information on hard and soft tissue to analyse them three-dimensionally [25].

Santoro et al. [26] showed a significant difference between plaster and digital model measurements with respect to both tooth width and overbite. While the digital model measurements were consistently smaller than the plaster model measurements, the magnitude of these differences was so small that they were not considered to be clinically significant. DeLong et al. [27], using the Virtual Dental Patient System, compared standard measurements from the actual object and from the stone model to the measurements

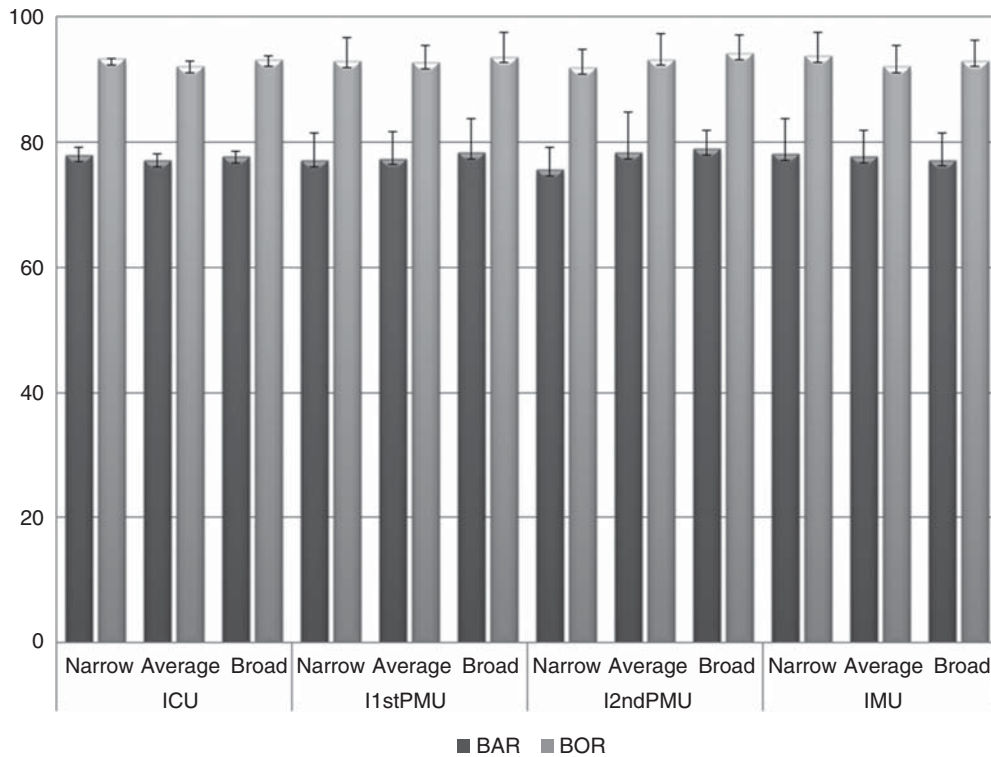


Figure 3. Anterior and overall ratio in upper arch width groups. BAR, Bolton anterior ratio; BOR, Bolton overall ratio; \*  $p < 0.05$ ; ICU, inter-canine width upper arch groups; I1stPMU, inter-first premolar upper arch width groups; I2ndPMU, inter-second premolar upper arch width groups; IMU, inter-molar upper arch width groups. ANOVA was used to test the significant differences.

obtained from a digitized model. The results showed that the digital models were clinically acceptable.

Tooth size, crowding or spacing, overjet, overbite and Bolton analysis are typically measured manual

methods (digital calipers) on study models. The 3D digital model is a valuable alternative to conventional study models and can be used to determine routine diagnostic values, such as the Bolton analysis, arch

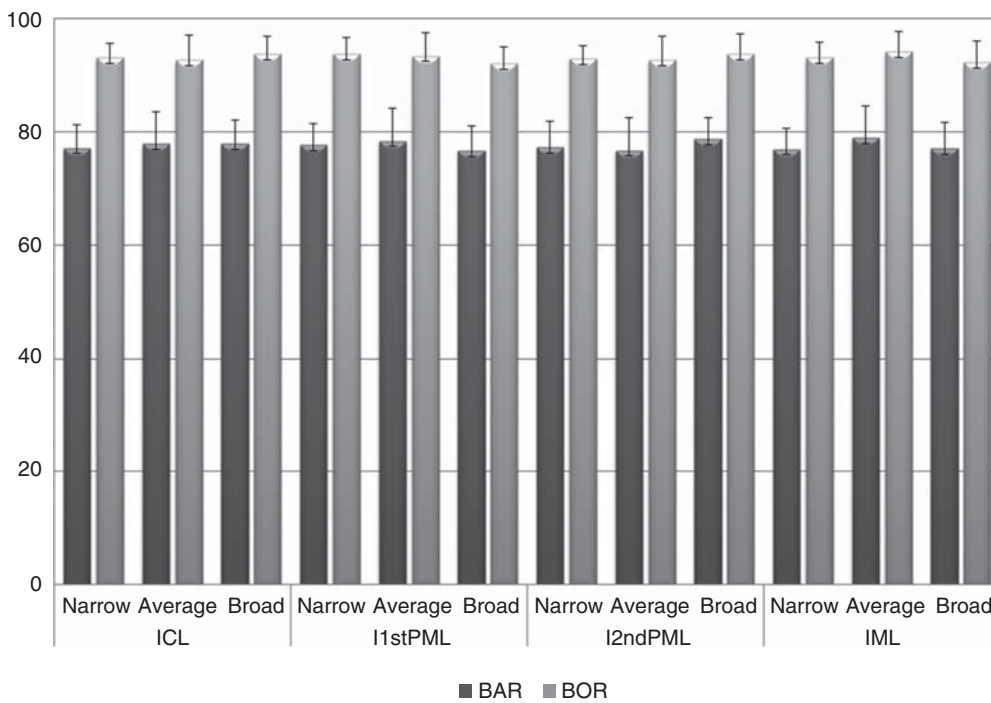


Figure 4. Anterior and overall ratio in lower arch width groups. BAR, Bolton anterior ratio; BOR, Bolton overall ratio; \*  $p < 0.05$ ; ICL, inter-canine width lower arch groups; I1stPML, inter-first premolar lower arch width groups; I2ndPML, inter-second premolar lower arch width groups; IML, inter-molar lower arch width groups. ANOVA was used to test the significant differences.

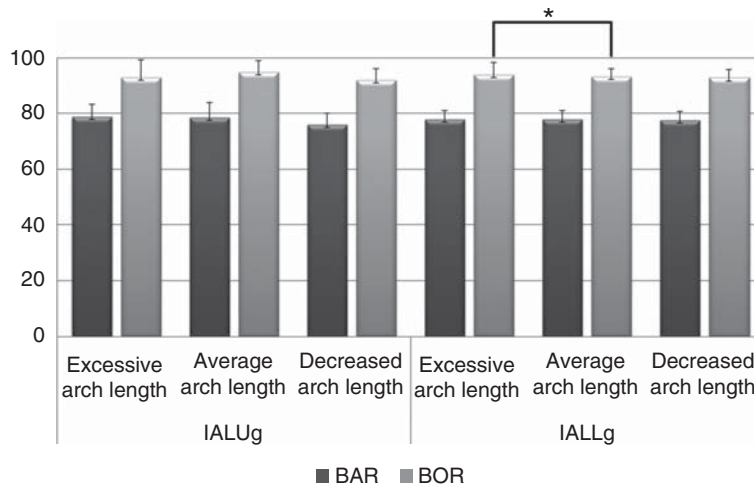


Figure 5. Anterior and overall ratio in arch length groups. BAR, Bolton anterior ratio; BOR, Bolton overall ratio; \*  $p < 0.05$ ; IALUg, inter-arch length upper groups; IALLg, inter-arch length lower groups. ANOVA was used to test the significant differences.

length discrepancy, sagittal or transverse symmetry [26,28].

Cultural and environmental factors can influence and show variations in tooth morphology [29]. These apparently differ in the Caucasoid, Negroid and Mongoloids populations [30]. The tooth size has the specific proportion to be seat in good occlusion for the anterior and overall ratio of the maxilla and mandible [6]. The anterior and overall ratio of the various population (Bangladeshi, Nepalese, Malay, Chinese, Japanese, Peruvian, Brazilian, Saudi, Turkey and Pakistani population) shows a deviation from the Bolton’s standard, all the measurement are via callipers [2,10–20]. Dental measurements, anterior and overall Bolton ratios calculated on CBCT showed acceptable values, indicating that CBCT measurements could be used instead of those obtained from conventional plaster models [22].

In our study we used the 3D tooth size measurements via CBCT acquisitions. We compared the Bolton tooth size ratio 3-dimensionally in relation to the arch width, arch length and arch perimeter groups. No studies have evaluated the tooth size ratio BAR and BOR in relation to arch width, arch length and arch perimeter groups. We found significant differences concerning mandibular excessive arch length and average arch length in relation to BOR and various arch perimeter groups in relation to the BAR; this might be due to polygenetic inheritance on formation of tooth germs and the genes that control maxillary and/or mandibular dimensions In a prospect study, these need to be studied. These findings, a using 3D CBCT acquisition, were obtained from Malay subjects at HUSM. Whether comparable findings might be obtained in another population is unknown. Conducting this 3D CBCT acquisition

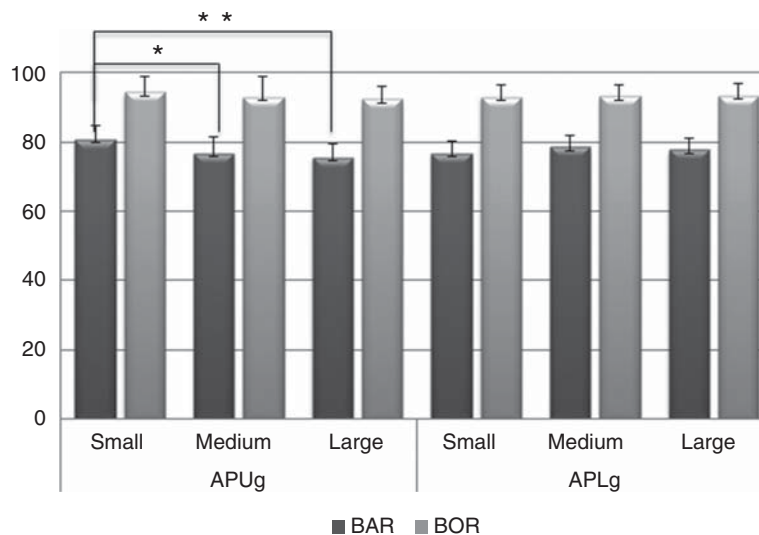


Figure 6. Anterior and overall ratio in arch perimeter groups. BAR, Bolton anterior ratio; BOR, Bolton overall ratio; \*  $p < 0.05$ , \*\*  $p < 0.01$ ; APUg, Arch perimeter upper groups; APLg, Arch perimeter lower groups. ANOVA was used to test the significant differences.

in study populations from other institutions might be beneficial for proper orthodontic treatment planning.

Our study is not free from limitations. One of the important limitations is the utilization of a small sample size, which may limit the reliability of the findings. A hospital-based sample and geographical restrictions in the study location also limit the widespread applicability of the findings.

## Conclusions

Tooth size ratio during orthodontic treatment for different arch length and arch perimeter groups needs to be evaluated carefully. Arch length and arch perimeter groups, in relation to tooth size ratio, need to be investigated on various populations. Based on our results, the following conclusions can be drawn:

- (1) No significant difference was found in the sexual comparison.
- (2) BOR and BAR in relation to the arch width groups also showed no significant differences.
- (3) There were statistically significant differences between the mandibular excessive arch length and average arch length in relation to BOR.
- (4) There were statistically significant differences observed among the various arch perimeter groups in relation to the BAR.

**Declaration of interest:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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