ORIGINAL RESEARCH

Mandibular Interincisor and Intercanine Width at Three Different Stages of Dentition: A Cross-sectional Study

Parul Singhal[1], Oshin Jaswal[2], Seema Thakur[3]

Abstract

Background and objective: Malocclusion is a manifestation of normal biological variability, defined as a misalignment of the teeth or an incorrect occlusion between the upper and lower dental arches. This study aimed to evaluate the mandibular intercanine primary, mixed, and permanent dentition in school children of Shimla, Himachal Pradesh.

Materials and methods: This cross-sectional study was conducted on 1,392 children between the ages of 4 and 18 years from schools that fulfilled the inclusion criteria. The dental casts were poured and further divided based on the dentition stage, i.e., primary, mixed, and permanent dentition stages. Mandibular arch widths—interincisor and intercanine were measured on the casts by a digital vernier caliper.

Results: The statistically significant difference was found as the interincisor width increased from primary to mixed dentition and between males and females for permanent dentition. Intercanine width significantly increases from primary to mixed dentition and gradually from mixed to permanent dentition stages.

Conclusion: The present study found that there is a significant increase in interincisor and intercanine width in the lower dental arch from primary dentition to permanent dentition.

Keywords: Dental arch, Dimension, Intercanine width, Interincisor width, Mandible.

International Journal of Clinical Pediatric Dentistry (2024): 10.5005/jp-journals-10005-2839

Introduction

Harmonious integration of the many parts of the craniofacial complex results in balanced facial features and functions. The dental arch is balanced with the craniofacial features in the natural dentition, which depicts a balanced position between the tongue and the surrounding muscles.[1] More variable than the skull is mandibular morphology, which has been influenced by both genetics and the environment. During the course of evolution, the length of the mandible and the inferior dental arch have reduced for functional adaptations, and the width has increased as the brain broadened.[2]

In dentofacial orthopedics, the mandibular dental arcade is regarded as the primary reference point for diagnosis and treatment. Understanding the changes in the dental arch that untreated normal persons experience during their active growing years and beyond is particularly crucial since it serves as a foundation for the planning of orthodontic therapy. The primary determinant of the stability of the therapeutic outcomes is the mandibular dental arcade's form and size stability.[3]

Racial and ethnic disparities are becoming more significant in today's mixed society. No studies have been documented that demonstrate alterations in lower interincisor width and lower intercanine width from primary to permanent dentition, despite the fact that numerous investigations have been conducted on the malocclusion status of children in Himachal Pradesh. This study examined the cross-sectional variations in interincisor and intercanine width between primary, mixed, and permanent dentition in children aged 4–18, living in Shimla, a city in the northern hilly state of India.

Materials and Methods

This cross-sectional investigation was carried out in the Department of Pediatric and Preventive Dentistry, Government Dental College and Hospital, Shimla, Himachal Pradesh, India. The Institutional Ethics Committee has given its approval for the study. For the study, 1,392 participants between the ages of 4 and 18 were evaluated at various schools. Each participant provided informed consent, and the study's goal and methodology were described to the school's head. Among these examined subjects, 180 impressions were poured. Subjects with proximal caries, wear and restoration or fracture in the mandibular arch, crowding in teeth, history of orthodontic treatment, alteration in size, shape, and number of teeth were excluded. The broken casts with bubbles on the canine and lateral tips were not included in the selection process. In conclusion, 165 casts in total were included in the study, and these were split into three groups according to the dentition status: group I—primary dentition, group II—mixed dentition, and group III—permanent dentition. Measurements of the arch dimensions like interincisor width and intercanine width were measured with a digital Vernier caliper with an accuracy of 0.02/100 mm (ZHART Electronics, India).

For each cast following were measured:

- Interincisal width.
- Intercanine width.

[1–3]Department of Pediatric and Preventive Dentistry, HP Government Dental College & Hospital, Shimla, Himachal Pradesh, India

Corresponding Author: Oshin Jaswal, Department of Pediatric and Preventive Dentistry, HP Government Dental College & Hospital, Shimla, Himachal Pradesh, India, Phone: +91 7018314756, e-mail: oshinjaswal@gmail.com

How to cite this article: Singhal P, Jaswal O, Thakur S. Mandibular Interincisor and Intercanine Width at Three Different Stages of Dentition: A Cross-sectional Study. Int J Clin Pediatr Dent 2024;17(4):417–424.

Source of support: Nil

Conflict of interest: None

Interincisal Width

The linear distance between the distal contact point of the permanent lateral incisor on one side and the distal contact point of the contralateral permanent lateral incisor was measured in the primary dentition. In the mixed and permanent dentition, the linear distance was measured between the distal contact points of the permanent lateral incisor on one side and the contralateral permanent lateral incisor (Fig. 1).

Intercanine Width

The linear distance between deciduous canine cusp tips in primary and mixed dentition, and the linear distance between permanent canine cusp tips in permanent dentition, were measured (Fig. 1).

Measurement Reliability

Using a vernier caliper that was accurate to 0.02 mm, measurements were taken for each parameter. Around 1 week following the first measurements, 30% of the sample castings were randomly selected for second measurements. The intraclass correlation coefficient (ICC) test was used to assess intraobserver reliability with a value ranging from 0.928 to 0.978, which was considered excellent.

Statistical Analysis

The mean and standard deviation (SD) for the continuous variables were computed for descriptive statistics. Categorical variables were presented as percentages and absolute values. Software used for statistical analysis included MedCalc and Statistical Package for the Social Sciences (SPSS) version 25.0. Statistical tests employed included one-way analysis of variance (ANOVA), *post hoc* testing, and the Chi-squared test.

Results

A total of 1,392 participants were assessed for the study in several schools, with an age range of 4–18 years. Among these subjects, 180 were selected for impression making. Dental castings with bubbles on the canine tips and central fissure areas of the molars were excluded from the study. Finally, the study included a total of 165 casts, which were divided into three groups based on dentition status. Using a vernier caliper, measurements of the arch's dimensions, such as interincisor and intercanine width, were taken on the casts.

Table 1 and Figure 2 depict that in group III, the mean interincisal width was significantly greater among males compared to females (p-value = 0.001). Interincisal width in group I was lower compared to groups II and III, and this difference was statistically significant (p-value = 0.001). There was no statistically significant difference between group II and group III (p = 0.209).

Table 2 and Figure 3 illustrate the mean intercanine width (±SD) for each of the three groups using a vernier caliper. Intercanine width in group I was lower than in group II and group III, and this difference was found to be statistically significant (p-value = 0.001). There was no statistically significant difference between group II and group III (p = 0.194).

Discussion

The dental arch's parameters never stabilize. The key to a successful orthodontic treatment plan is a precise diagnosis. One of the most significant evaluated factors that has a significant impact on the orthodontic treatment strategy is the mandibular arch. Therefore, it becomes essential to understand the typical dentoskeletal parameters to plan future diagnoses and treatments. These dimensions depend on the specific dental arch form, gender,

Table 1: Distribution of study population according to interincisal width (mm)

	Male		*Female*		*Total*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*p-value*
Group I	17.61	1.11	17.68	0.93	17.63	1.05	0.817
Group II	22.37	1.26	21.81	1.32	22.11	1.31	0.114
Group III	21.77	0.99	20.75	1.10	21.31	1.15	0.001*
Group I vs group II *p*-value	0.001*		0.001*		0.001*		
Group I vs group III *p*-value	0.001*		0.001*		0.001*		
Group II vs group III *p*-value	0.178		0.190		0.209		

Table 1 and Figure 2 depict the mean (±SD) of Interincisal width using vernier caliper in the three groups; *significant

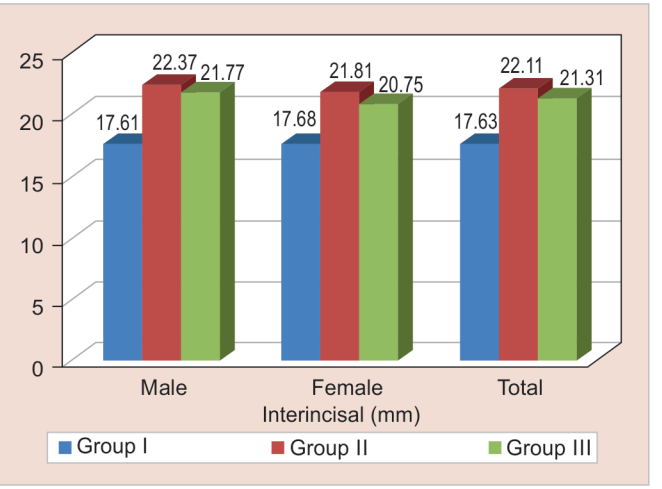
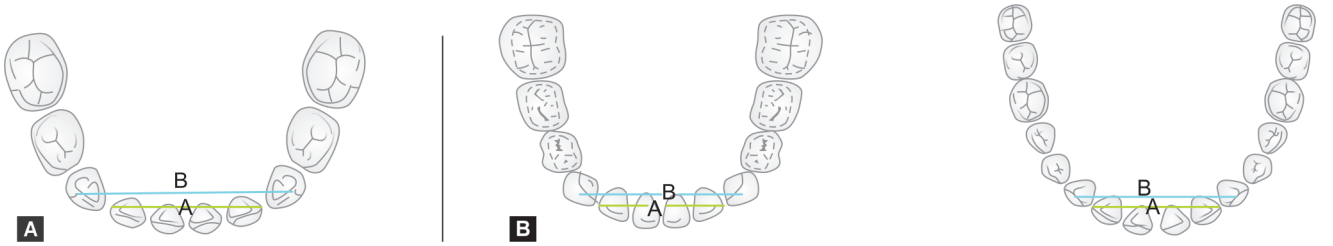


Fig. 2: Distribution of study population according to interincisal width (mm)



Figs 1A and B: (A) Interincisor distance; (B) Intercanine distance in primary, mixed, and permanent dentition, respectively

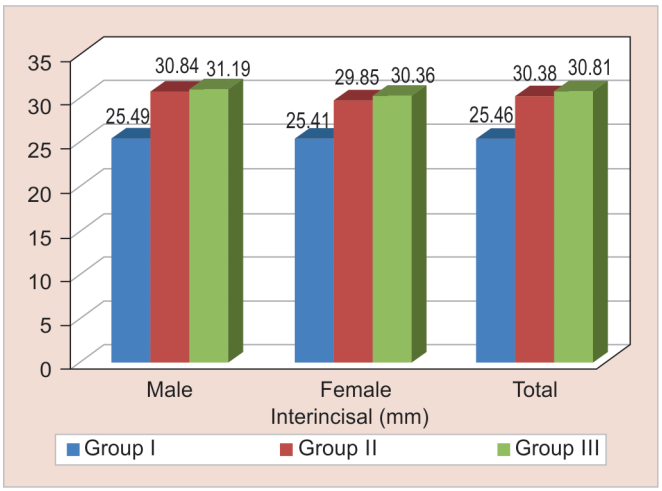


Fig. 3: Distribution of study population according to intercanine width (mm)

Table 2: Distribution of study population according to intercanine width (mm)

	Male		*Female*		*Total*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*p-value*
Group I	25.49	2.21	25.41	1.93	25.46	2.10	0.894
Group II	30.84	1.78	29.85	1.64	30.38	1.78	0.037
Group III	31.19	1.76	30.36	1.99	30.81	1.90	0.120
Group I vs group II *p*-value	0.001*		0.001*		0.001*		
Group I vs group III *p*-value	0.001*		0.001*		0.001*		
Group II vs group III *p*-value	0.129		0.174		0.194		

Table 2 and Figure 3 illustrate the mean (±SD) of intercanine width using vernier caliper in the three groups; *significant

ethnicity of the patient, and age.[4] The current investigation was carried out to assess the results of interincisor and intercanine widths in different dentition stages in the population of Shimla city.

The results of this study showed notable changes in dentition from the primary to the adult stage. Males exhibited greater interincisor and intercanine widths compared to females. This difference was statistically significant in measurements between males and females in permanent dentition.

The anterior section propagated as a result of the permanent incisors erupting.[5] An overall increase of 4.75 mm in interincisor width and a statistically significant shift from primary dentition to mixed dentition was discovered ($p < 0.001$). A decrease of 0.8 mm from mixed to permanent dentition was found. Similar results were obtained by a study done by Knott,[6] which found an increase of 3.5 mm from primary to mixed dentition, followed by a decrease of 0.5 mm in permanent dentition. One possible explanation for the ongoing alteration of the dental arches is that they represent a biological migration of the teeth, leading to anterior crowding, particularly in the mandible.[5] A description of studies done on mandibular interincisor width is given in Table 3.

The intercanine width in the current study was measured as 25.46 ± 2.1 mm in primary dentition, which increased to 30.38 ± 1.78 mm in mixed dentition. A statistically significant increase of 4.92 mm was found. These results were analogous to the results found in a study done by Barrow and White[13] and Moores et al.[14] They reported a similar increase of 3 mm between the ages of 5 and 9 years whereas Knott[6] cited an increase of 2.8 mm and Ross-Powell and Harris[15] reported an increase of 4 mm with the eruption of permanent incisors.

As the dentition transitioned, an increase of 0.43 mm was found from mixed to permanent dentition. Studies done by Knott,[6] Ross-Powell and Harris,[15] and Arslan et al.[16] found similar results but there were few studies that contrasted these results and noticed a decrease of intercanine width from mixed to permanent dentition, Hassanali and Odhiambo[17] reported a decrease of 0.3–1.7 mm, whereas Thilander[5] reported a decrease of 0.4 mm. A summary of various studies done on mandibular intercanine width is described in Table 4.

Table 3: Description of studies of mandibular interincisor width in children

Serial number	*Author*	*Year*	*Ethnicity*	*Age-group*	*Type of Study*	*Sample size*	*Dentition studied*	*Results*
1.	Foster et al.[7]	1969	British	2.5–3 years	Cross-sectional	100	Primary dentition	The interincisor dimension for males was recorded to be 13.71 mm which was less in females 12.80 mm and the difference between the two was significant ($p < 0.05$)
2.	Knott[6]	1972	American, Caucasian	5.4–25.9 years	Longitudinal	Unknown	Primary, mixed, and permanent dentition	In primary dentition, width was 18.1 mm for males, and 17.6 mm in females, in mixed dentition, it was 21.7 mm males, 21.1 mm for females, and in permanent 21.2 mm for males and 20.9 mm for females. From primary dentition to mixed dentition there was an increase of 3.5 mm in both sexes. The mandibular interincisal width decreased over 0.6 mm after the age of 13
3.	Ingervall et al.[8]	1972	Swedish	8–11 years	Observational	324	Mixed	The mean for interincisor width was found to be 22.98 mm

Contd…

Table 3: *Contd…*

Serial number	*Author*	*Year*	*Ethnicity*	*Age-group*	*Type of Study*	*Sample size*	*Dentition studied*	*Results*
4.	Radnzic[9]	1988	British and Pakistani immigrants	13–15 years, 11 months	Observational	120	Permanent dentition	Crowded arches have smaller intermolar widths in both the groups. Pakistani group mean for crowded arches was 20.55 mm and for noncrowded was 24.10 mm ($p < 0.01$). British group it was 20.89 mm for crowded arches and 22.75 mm for noncrowded ($p < 0.01$)
5.	Cassidy et al.[10]	1998	Northern European	13.8–48.6 years	Longitudinal	82	Permanent dentition	Mean ± SD (mm) in permanent dentition was 19.2 ± 1.55 in males and in females it was 18.7 ± 1.41($p < 0.01$). Arch size, in permanent dentition, was significantly larger in males than in female's dimensions up to 3–5%
6.	Yadav et al.[11]	2014	Indian	Above 18 years	Cross- sectional	120	Permanent dentition	Interincisor width was greater for nontribe subjects in comparison to Bhil tribe's subjects. It was 21.20 mm (±1.61 mm) for nontribe subjects and 20.50 mm (±1.19 mm) for Bhil tribe subjects
7.	Alkadhi et al.[12]	2018	Saudi Arabia	18–33 years	Cross-sectional	169	Permanent dentition	Interincisor width showed statistically significant greater values for males which was 21.45 ± 0.15 mm and in females 20.86 ± 0.15 mm ($p < 0.007$)

Table 4: Description of studies of mandibular intercanine width in children

Serial number	*Author*	*Year*	*Ethnicity*	*Age-group*	*Type of study*	*Total number of subjects examined*	*Dentition studied*	*Results*
1.	Sillman[18]	1964	American white	Birth to 25 years	Longitudinal	750 casts of 65 children	Primary, mixed and permanent dentition	From birth to 2 years increase was 3.5 mm in ICW. From 2–12 years there was continuous increase. From 12 to 20 years there was no evidence of significant increase
2.	Foster et al.[7]	1969	British	2.5–3 years	Cross-sectional	100	Primary dentition	The intercanine dimension for males was recorded to be 23.55 mm which exceeded those of females 22.02 mm and the difference between the two was not significant ($p > 0.05$)
3.	Knott[6]	1972	Caucasoid primarily northwest European ancestry	5.4–25.9 years	Longitudinal	Unknown	Primary, mixed, and permanent dentition	In males from primary dentition to mixed dentition there was increase of 2.8 mm in ICW. Mean dental ICW in deciduous dentition, mixed dentition and permanent dentition was 28.5, 31.3, and 31.6 mm in males, respectively, and in females, it was 27.0, 29.9, and 30.3 mm for deciduous, mixed and permanent dentition, respectively

Contd…

Table 4: *Contd…*

Serial number	*Author*	*Year*	*Ethnicity*	*Age-group*	*Type of study*	*Total number of subjects examined*	*Dentition studied*	*Results*
4.	Sinclair[19]	1983	Canadian	6.18–21.83 years	Longitudinal	65	Mixed dentition and permanent dentition	Both sexes showed statistically significant ($p < 0.01$) decreases of ICW from the mixed-dentition stage into early adulthood (E = −0.75 + 1.45 mm). Constriction of the male group was gradual over the entire period while the females had the major change during the permanent-dentition stage
5.	Grewe[20]	1970	American Indian	6–19 years	Cross-sectional		Mixed, permanent dentition	The mandibular ICW was found to be greater in Navajo and Chippewa Indians compared to the Caucasian group for all ages and both genders. At age 7, the Chippewa ICW was less than Navajo ($p > 0.05$). In Navajo male and female children the mean for ICW was 26.6 mm at age 6. By 8 years, it became 29.3 mm for males and 29.2 mm for females and remained constant even at age 12. In Chippewa males ICW at age 6 was 26.6 mm and for females it was 25.8 mm. By age 8, it became 29.5 mm in males and 28.7 mm in females at age 9
6.	Arslan et al.[16]	2007	Turkish	Mean age is 8.98–9.64 years	Longitudinal	65	Mixed dentition, permanent dentition	ICW had no statistically significant differences in girls and in boys. Mean increase was 0.33 mm from mixed dentition to early permanent dentition with SD of 1.9 which was not statistically significant
7.	Anderson[21]	2006	European American and African American	3–6 years	Cross-sectional	217	Primary dentition	Gender dimorphism was statistically nonsignificant ($p < 0.001$) for ICW. However, ICW for African American boys was 24.4 mm which was more than in European American boys 21.8 mm (p-value < 0.001). In girls also the ICW was more in African American girls 24.1 mm and in European Americans 21.7 mm (p-value < 0.001)
8.	Thilander[5]	2009	Swedish	5–31 years	Longitudinal	436	Primary, mixed, and permanent dentition	In the mandible, an increase of the same degree was recorded at the age of 10 years followed by a continuous decrease. The mean for primary dentition was found to be for males 23.7 mm and for females 22.2 mm, in mixed dentition it was for males 27.8 mm and for females it was 25.9 mm and in permanent dentition the mean was 27.3 mm and 25.6 mm for males and females, respectively

Contd…

Table 4: *Contd…*

Serial number	*Author*	*Year*	*Ethnicity*	*Age-group*	*Type of study*	*Total number of subjects examined*	*Dentition studied*	*Results*
9.	Fabiane et al.[22]	2011	Brazilian	9–12 years	Cross-sectional	66	Mixed dentition	The mean ± SD (mm) decrease in ICW was noticed from 21.9 ± 1.7 at 9 years of age to 20.7 ± 1.1 at 12 years of age, this change being statistically nonsignificant ($p = 0.334$). For females at 9 years ICW was 21.43 mm which reduced to 20.46 mm at 12 years of age. Similarly, for males at 9 years it was 22.73 mm which reduced to 20.96 mm at 12 years of age
10.	Ahn et al.[23]	2012	Korean	6–14 years	Longitudinal	66	Primary, mixed, and permanent dentition	The ICW of the deciduous canines increased from ages 6 to 8 years in mandible, in both girls and boys. The mean intercanine widths at 14 years of age were 27.14 mm in the girls and 29.17 mm in the boys. There were statistically significant differences between sexes in the ICW of the mandible at 10, 11, 12, 13, and 14 years of age. From 8 to 14 years of age, the total changes in mean ICW over 4 years were 0.54 mm in the girls and −1.96 mm in the boys. However, when observation period was limited from 10 to 14 years of age, the total mean changes were −0.18 mm in the girls' mandibles, and −0.11 mm in the boys
11.	Okori et al.[24]	2015	Ugandans	12–17 years	Secondary analysis	220	Permanent dentition	With respect to age, the mandibular ICW ($p < 0.01$) was the measurement with statistically significant difference in the means of the respective study age-groups. For gender, significant differences were observed in the intercanine distance. $p < 0.01$ was larger in male participants. The width was 26.72 mm at 12–14 years which increased to 27.24 mm at 15–17 years
12.	Dung et al.[25]	2019	Vietnamese	7 years	Cross-sectional	3204 children	Mixed dentition	Intercanine dental arch dimensions were not significantly different between two genders. There was no difference among four ethnic groups adjusted by gender. Mean for all ethnic groups was found to be 26.99 mm in males and 26.89 mm in females

Contd…

Table 4: *Contd…*

Serial number	*Author*	*Year*	*Ethnicity*	*Age-group*	*Type of study*	*Total number of subjects examined*	*Dentition studied*	*Results*
13.	Hussain and Nasser[26]	2019	Saudi Arabia	9–11 years	Cross-sectional	15	Mixed dentition	The mean ICW values at the 1st (25.37 mm) and the 3rd stages (25.67 mm), ($p = 0.002$), and at the 2nd (26.20) and 3rd stages (25.67 mm) ($p = 0.001$) were statistically different but were not different at the 1st and the 2nd stages ($p = 0.154$)
14.	Smitha et al.[27]	2020	Dravidian race, Mongoloid race	11–14 years	Cross-sectional	40	Mixed dentitions with permanent canines and first molars	Mean mandibular intercanine width of group I was 27.2 mm, whereas mean width of group II was 24.8 mm, it was not statistically significant
15.	Sharaf et al.[28]	2022	Egyptian	4–14 years	Cross-sectional	191	Primary dentition, mixed dentition and, permanent dentition	Mandibular intercanine width was observed during transition from primary dentition (23.38 mm) to mixed dentition (24.98 mm), and then, marked increase was noticed during transition to permanent dentition (28.01 mm). Difference between the two genders revealed that males had higher values than females which were statistically significant ($p < 0.05$)

ICW, intercanine width

Anterior crowding, particularly in the jaw, can be explained by the biological migration of teeth, as evidenced by the ongoing alteration of the arches. Different racial groups exhibit distinct facial forms and anthropometric measurements, which may explain variations in mandibular jaw width and length across different regions of the world. Moreover, various studies on mandibular dimensions have employed different reference points and measuring instruments compared to the present study, which could contribute to differing findings.

Limitations of the present study were:

- It was a cross-sectional study, and as such, continuous growth changes in the mandible were not measured as in various longitudinal studies.
- Birth history and nutritional status of the children were not recorded, factors that may influence the growth and development of the child.

More studies are required to investigate various dental arch dimensions using a larger and more diverse study sample in terms of age.

Conclusion

As ethnicity varies, so do the dimensions in different populations. Although the intercanine width increases from primary to permanent dentition, the interincisor width increases from primary to mixed dentition but decreases in permanent dentition.

Orcid

Oshin Jaswal https://orcid.org/0009-0005-3180-5252

References

1. Park SJ, Leesungbok R, Song JW, et al. Analysis of dimensions and shapes of maxillary and mandibular dental arch in Korean young adults. J Adv Prosthod 2017;9(5):321–327. DOI: 10.4047/jap.2017.9.5.321
2. Xu MC, Jeong JS, Chen ZH, et al. Evolutionary trends in human mandibles and dentition from Neolithic to current Chinese. Arch Oral Biol 2022;142:105512. DOI: 10.1016/j.archoralbio.2022.105512
3. Raberin M, Laumon B, Martin JL, et al. Dimensions and form of dental arches with normal occlusions in subjects. Am J Orthod Dentofacial Orthop 1993;104(1):67–72. DOI: 10.1016/0889-5406(93)70029-N
4. Adamek A, Minch L, Kawala B, et al. Reviews intercanine width-review of the literature. In Dent Med Probl 2015;52(3):336–340.
5. Thilander B. Dentoalveolar development in subjects with normal occlusion. A longitudinal study between the ages of 5 and 31 years. Eur J Orthod 2009;31(2):109–120. DOI: 10.1093/ejo/cjn124
6. Knott VB. Longitudinal study of dental arch widths at four stages of dentition. Angle Orthod 1972;42(4):387–394. DOI: 10.1043/0003-3219(1972)042<0387:LSODAW>2.0.CO;2
7. Foster TD, Hamilton MC, Lavelle CLB. Dentition and dental arch dimensions in British children at the age of 24 to 3 years. Archs oral Bid 1969;14(9):1031–1040. DOI: 10.1016/0003-9969(69)90073-9
8. Ingervall B, Seeman L, Thilander B. Relation between combined widths of incisors and dimensions of the dental arches. Scand J Dent Res 1972;80(3):181–188. DOI: 10.1016/0003-9969(69)90073-9

9. Radnzic D. Dental crowding and its relationship to mesiodistal crown diameters and arch dimensions. Am J Orthod Dentofac Orthop 1988;94(1):50–58. DOI: 10.1016/0889-5406(88)90450-7
10. Cassidy KM, Harris EF, Tolley EA, et al. Genetic influence on dental arch form in orthodontic patients. The Angle Orthodontist 1998;68(5):445–454. DOI: 10.1043/0003-3219(1998)068<0445:GIODAF>2.3.CO;2
11. Yadav NS, Saxena V, Vyas R, et al. Morphological and dimensional characteristics of dental arch among tribal and non-tribal population of Central India: a comparative study. J Int Oral Health 2014;6(6):26–31.
12. Alkadhi OH, Almahfouz SF, Tokhtah HA, et al. Dental arch dimensions in Saudi adults. Int J Dent 2018;2018:2190250. DOI: 10.1155/2018/2190250
13. Barrow GV, White JR. Developmental changes of the maxillary and mandibular dental arches. Angle Orthodontist 2009;22:41–46.
14. Moores F, Gren AM, Lebret LM, et al. Growth studies of the dentition: a review. Am J Orthodontics 1969;55(6):600–616. DOI: 10.1016/0002-9416(69)90037-2
15. Ross-Powell RE, Harris EF. Growth of the anterior dental arch in black American children: a longitudinal study from 3 to 18 years of age. Am J Orthod Dentofac Orthop 2000;118(6):649–657. DOI: 10.1067/mod.2000.110811
16. Arslan SG, Kama JD, Şahin S, et al. Longitudinal changes in dental arches from mixed to permanent dentition in a Turkish population. Am J Orthod Dentofac Orthop 2007;132(5):576.e15–576.e21. DOI: 10.1016/j.ajodo.2007.06.009
17. Hassanali J, Odhiambo JW. Analysis of dental casts of 6-8 and 12-year-old Kenyan children. Eur J Orth 2000;22(2):135–142. DOI: 10.1093/ejo/22.2.135
18. Sillman J. Dimensional changes of the dental arches: longitudinal study from birth to 25 years. Am J Orthod 1964;50(11):824–842. DOI: 10.1016/0002-9416(64)90040-5
19. Sinclair PM, Little RM. Maturation of untreated normal occlusions. Am J Orthod 1983;83(2):114–123. DOI: 10.1016/s0002-9416(83)90296-8
20. Grewe JM. Intercanine width variability in American Indian children. Angle Orthod 1970;40(4):353–358. DOI: 10.1043/0003-3219(1970)040<0353:IWVIAI>2.0.CO;2
21. Anderson AA. The dentition and occlusal development in children of African American Descent Biometrics of the primary dentition. Angle Orthod 2007;77(3):421–429. DOI: 10.2319/0003-3219(2007)077[0421:TDAODI]2.0.CO;2
22. Fabiane L. Dental arch dimensions in mixed dentition: a study of Brazilian children from 9 to 12 years of age. J Appl Oral Sci 2011;19(2):169–174. DOI: 10.1590/s1678-77572011000200014
23. Ahn JS, Park MS, Cha HS, et al. Three-dimensional interpretation of intercanine width change in children: a 9-year longitudinal study. Am J Orthod Dentofac Orthop 2012;142(3):323–332. DOI: 10.1016/j.ajodo.2012.04.012
24. Okori H, Apolot PS, Mwaka E, et al. A secondary analysis to determine variations of dental arch measurements with age and gender among Ugandans. BMC Res Notes 2015;8(1):428. DOI: 10.1186/s13104-015-1411-6
25. Dung TM, Nhu Ngoc VT, Khoi TD, et al. The dental arch dimensions in Vietnamese children at 7 years of age, and their variation by gender and ethnicity. J Oral Biol Craniofac Res 2019;9(3):236–240. DOI: 10.1016/j.jobcr.2019.06.004
26. Hussain AA, Nasser A. Changes in the mandibular dental arch during the late mixed dentition stage: experimental study. J Pak Med Assoc 2019;69(1):77–81.
27. Smitha S, Nagar P, Abinaya R. Comparing the arch forms between mongoloid race and Dravidian race in 11–14-year-old children. Int J Clin Pediatr Dent 2020;13(Suppl 1):S26–S28.
28. Sharaf RF, Radwan E, Salem GA, et al. Dental arch form and arch dimensions among a group of Egyptian children and adolescents. Bull Natl Res Cent 2022;46(1). DOI: 10.1186/s42269-022-00887-w