ORIGINAL ARTICLE

Gender Determination in Pakhtun Pakistani Population Using Dental Arch Dimensions: A Digital Model Study

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ABSTRACT

Introduction: In circumstances where the ante mortem list is unknown, gender determination would exclude one-half of the population, aid in a more precise search of the ante mortem records. This study aims to formulate gender prediction models in the Pakhtun Pakistani population using digital dental arch dimensions. **Methods:** Data collection and analysis of the dental casts were conducted on 128 subjects, 64 males and 64 females from the Pakistani population. The mean age of the subjects was 19.2 years old. Several linear dental arch dimensions were measured and recorded for both upper and lower arches. **Results:** It was found that gender differences in linear arch dimensions were statistically significant for both males and females ($p<0.05$); in which the arch dimensions for the males were larger than the arch dimensions for the females. Stepwise discriminant function analysis found that the highest discriminant power of the variables was present within the inter-second premolar width for the upper arch and inter-molar width for the lower arch. These variables significantly contributed to gender variance. Moreover, the prediction of 67.2% of original grouped cases for the upper arch and 66.4% of cross-validated group cases was correct. Similarly, the correct prediction was made on 64.8% of original grouped cases for the lower arch and 64.1% of cross-validated group cases. **Conclusion:** The dental arch dimensions were larger among the males compared to the females. Prediction models obtained in this study were moderately strong predictors which may be used as an adjunct to predict gender.
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INTRODUCTION

Teeth are resistant to putrefaction and post mortem changes, thus allows valuable biological information to be preserved (1). This biological information consists of a group of specific individual characteristics would aid in age estimation, gender, race, socio-economic status, oral and systemic health, personal habits, occupation, familial relations, psychological characteristics and individual dietary status (2). Invasive and non-invasive methods are implemented during dental autopsy to compile dental reconstructive profile (3). In an event when the ante mortem list is unknown, post mortem dental profiles (e.g., gender determination) narrow down the potential ante mortem dental records by 50% (4). With the availability of post mortem and ante mortem records, confirmation of the deceased identity could be performed (3).

Many oral biological factors have been used for gender determination in forensic investigation with varieties accuracy. Craniometry and craniofacial morphology have been utilized for sexing unknown skulls with acceptable accuracy (5). Tooth sizes have shown a good accuracy in gender prediction for many populations including South Asians population. In addition to tooth sizes method, Rao et al. have proposed an arch index, which utilized lower canine mesio-distal size and inter-canine dimension (6). They found a high accuracy of gender determination for South Indian population. However, other researchers Narang et al. (7) and Rocha et al. (8) found diverse accuracy as low as 20% to as high as 94% when this index was applied to several different ethnic groups.

Dental arch dimensions and shape is unique in different human ethnic groups (9). For instance, Caucasians have smaller inter-canine width and inter-molar width than Japanese. Furthermore, arch dimensions are also larger in males than in females (10). Similarly, few more studies in other populations which measured linear absolute dimension found that dental arch dimensions were larger in males than in females (11–15). These outcomes showed potential of using arch size variables for gender prediction which require further investigations of their applicability in forensic services. However, reports on gender prediction models complete with error rates were lacking (6,7,16,17).

Essentially, the establishment of population-specific values is important because dental arch size is influenced by the interplay between genetic and environmental factors (18). To our knowledge, there has been no study to determine the gender prediction models using dental arch dimensions of the Pakistani population. Therefore, this study aims to formulate gender prediction models using linear dental arch dimensions for Class I Pakhtun Pakistani population.

MATERIALS AND METHODS

Subjects

This cross-sectional study implemented the convenience sampling method on the dental casts belong to Pakhtun Pakistani population. Ethics approval was obtained beforehand from the Ethics Committee of the Universiti Sains Malaysia (USM/JEPeM/140376). Dental impressions were taken after written consent was obtained using alginate material (Zhermack Orthoprint ISO 1563 – ADA 18, Italy) and poured with dental stone (Type III hard plaster quick stone, China). The total lapse was approximately less than one hour between impression and pouring process.

Sample size calculation

The sample size was estimated based on the minimum ratio 20:1 to ensure the generalisability of results of discriminant function analyses (19). A total of six predictor variables were present, namely inter-canine width, inter-first premolar width, inter-second premolar width, inter-molar width, arch perimeter and arch length for upper and lower arch each thus at least 120 samples were required.

Inclusion criteria

The subjects were selected from the Pakhtun Pakistani population through interviews. The subjects who aged between 18 to 21 years old and had all sound permanent teeth, except the third molar,. Class I incisor relationship according to the British Standards Institute Class I molar and canine relationship and a straight profile were included in the study.

Exclusion criteria

The subjects with crowding, cross bite, spacing and craniofacial anomalies, interproximal caries, restoration, occlusal and the proximal tooth wear, which obscured the landmark for arch measurement and tooth anomalies were excluded. This exclusion was also imposed on damage casts.

Fabrication of digital models

The upper and lower arches of dental casts were scanned using a low magnification lens of digital stereomicroscope (HIROX KH7700, Japan). The digital microscope was equipped with automated calibration system (ACS), whereby the ratio of digital images size was maintained at 1:1. In order to standardize digital images, the dental casts were positioned with the occlusal plane parallel to the desktop. Measurement tools were included in the built-in software, and each measurement was automatically saved as a .csv file, which would later be exported into Excel.

Measurement of arch dimensions via HIROX digital stereomicroscope technique

Arch dimension measurements were performed using HIROX digital stereomicroscope, and the measurements obtained for arch dimensions are as follows in Fig. 1 and Fig. 2. The definitions and landmarks of the measurements were according to Harris (20) for arch perimeter and length; Alam et al. (21) for arch width i.e. intercanine, interpremolar and intermolar distances.

Study error

Inter and intra-observer errors were performed through a random selection of 20% of dental casts. Specifically, an inter-observer error was conducted by comparing the measurement between the operators, while the intra-observer error was evaluated through the comparison between two readings, which also included approximately two-week time interval between the first and second readings by the same operator. The intraclass correlation coefficient (ICC) was used to assess the reliability of inter and intra observer.

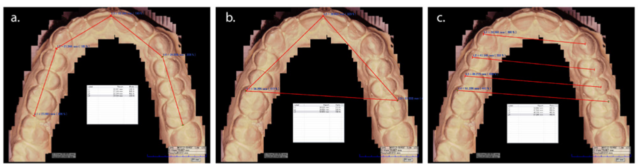

Figure 1: Landmarks for (a) upper arch perimeter, (b) upper arch length, and (c) upper arch width variables.

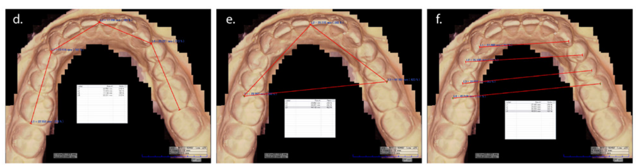

Figure 2: Landmarks for (d) lower arch perimeter, (e) lower arch length, and (f) lower arch width variables.

Statistical analysis

All statistical analyses of the data were performed using IBM SPSS Statistics Version 26 with significance level set at 5% ($p<0.05$). Descriptive statistics, which included mean, standard deviation, were computed for each variable. Furthermore, an independent sample t-test was performed to determine the presence of any statistically significant differences between males and females.

All predictor variables were investigated in the stepwise discriminant function analysis, which was conducted to formulate gender prediction models for upper and lower arch separately. Notably, this analysis had the potential for optimal separation of males and females, while statistical significance was assessed using Wilk's lambda. The criteria included F value, with the minimum partial for F enter amounting to 3.84 while the maximum partial for the removal of F amounting to 2.71. The predictor variables with higher discriminant function coefficient were included in the following discriminant function equation:

$$DF = a + b1x1 + b2x2 + \dots + b6x6$$

Where DF refers to a discriminant function score, while a denotes the discriminant function constant. The discriminant function coefficient is represented by b, while x refers to the score of the predictor variable.

RESULTS

The ICC for inter and intra observer reliability were in the range of 0.991 to 0.997 and 0.996 to 0.998 respectively. This study involved 128 subjects, which consisted of 64 males and 64 females from the Pakhtun Pakistani population. The mean age (standard deviation) among the subjects was 19.2 (1.1) years old, with 18 years old as the youngest age and 21 years old as the oldest age.

It was found that the mean arch dimensions were higher among males compared to females (Table I). Nevertheless, the standard deviation for each variable presented in the Table I was relatively small.

Generally, the mean differences between both genders were relatively small although the arches among the males were larger than females. Specifically, the lower arch perimeter exhibited the highest mean difference at 2.7 mm, followed by the upper arch length at 2.6 mm and upper arch perimeter at 2.4 mm. The lowest mean difference was observed in the lower inter-canine width, which amounted to 0.8 mm. Additionally, highly significant sexual dimorphism was found in the mean arch dimensions of the upper inter-canine width, upper inter-second premolar, upper inter-molar width, and lower inter-molar width.

Stepwise discriminant analysis was performed on the upper arch dimensions, lower arch dimensions and combined both to simulate forensic scenario. For upper arch dimension input, the upper inter-second premolar width was the only discriminator variable selected. The predictive equation or discriminant function (DF) was constructed for the upper arch dimension input as the following (refer to Table II);

DF = -20.524 + 0.427 (Upper inter-second premolar

Table I: Descriptive analysis and univariate gender dimorphism

Variables	Males (N=64)		Females (N=64)		Mean difference	*p*
	Mean	**SD**	**Mean**	**SD**		
Upper inter-canine width	36.1	1.97	34.3	2.35	1.8	<0.001
Upper inter-first premolar width	43.6	2.10	42.0	3.06	1.6	0.001
Upper inter-second premolar width	49.1	2.23	47.0	2.45	2.1	<0.001
Upper inter-molar width	54.0	2.52	52.2	2.34	1.8	<0.001
Upper arch length	130.2	4.58	127.6	5.20	2.6	0.003
Upper arch perimeter	97.2	4.72	94.8	4.16	2.4	0.002
Lower inter-canine width	27.0	1.92	26.2	1.82	0.8	0.026
Lower inter-first premolar width	35.9	1.98	34.6	2.16	1.3	0.001
Lower inter-second premolar width	41.9	2.56	40.4	2.57	1.5	0.002
Lower inter-molar width	46.7	2.50	45.2	2.36	1.5	<0.001
Lower arch length	111.4	4.23	109.8	4.93	1.6	0.061
Lower arch perimeter	90.6	5.15	87.9	3.73	2.7	0.001

*All units are in mm., *p* value - independent t-test,
*independent t-test was used

Table II: Discriminant function analysis for upper arch dimensions

Function	Variables	Discriminant function coefficients	Wilk's lambda	*p*	Group centroids	
					Males	**Females**
1	Upper inter-second premolar width	0.427	0.837	<0.001	0.438	-0.438
	(Constant)	-20.524				

width) --------------------------------------(1)
The cut score was zero.

The reliability of the derived discriminant function was assessed for the upper arch dimensions; which resulted in correct classification of 67.2% of original grouped cases. Following that, cross-validation was performed to determine whether the development of an accurate gender model for upper arch dimension was possible based on the collected data. As a result, 66.4% of cross-validated grouped cases were correctly classified (refer to Table III).

Table IV shows the lower inter-molar width was selected as the strongest predictor. The prediction model for lower arch input is as follows;
DF = -18.886 + 0.411 (Lower Inter-Molar Width) ---(2)

The percentage of correctly classified cases was 64.8% of original group. Similarly, cross-validation percentage was also slightly lower compared to the upper arch dimensions, as indicated from the correct classification of 64.1% of the cross-validated grouped cases for lower arch dimensions (refer to Table V).

For the third scenario (combined upper and lower arches input), stepwise procedure selected the upper inter-second premolar width as the only discriminator variable. Based on the result, a similar prediction model was generated as in prediction model 1.

DISCUSSION

The measurements of dental arch dimensions were performed using digital dental models instead of the digital calliper and plaster dental casts. Several studies (22,23) have confirmed the validity and reliability through the measurements performed on the digital dental models. Furthermore, the error study showed excellent reliability for all the tested variables, which prevented any bias in results. The dental casts were collected from the population aged 18 to 21 years old as the arch dimension growth has stabilized and minimal teeth attrition that may obscure the anatomical landmark in this age group (24). This study was standardized by including only the Class I occlusion sample because dental arch dimensions varied across different types of malocclusions (25,26).

Table III: Percentage of correct classification in the original and cross-validation samples for upper arch dimensions

Actual group membership	Predicted group membership		
	Males (count)	Females (count)	Total (count)
Original Sample			
Males	67.2 (43)	32.8 (21)	100.0 (64)
Females	32.8 (21)	67.2 (43)	100.0 (64)
Cross-validation			
Males	67.2 (43)	32.8 (21)	100.0 (64)
Females	34.4 (22)	65.6 (42)	100.0 (64)

[a]Correct classification was present in 67.2% of original grouped cases.
[b]Cross-validation was performed only on the analysis cases, in which each case was classified by the functions derived from all other cases.
[c]Correct classification was present in 66.4% of the cross-validated grouped cases.

Table V: Percentage of correct classification in the original and cross-validation samples for lower arch dimensions

Actual group membership	Predicted group membership		
	Males (count)	Females (count)	Total (count)
Original sample			
Males	65.6 (42)	34.4 (22)	100.0 (64)
Females	35.9 (23)	64.1 (41)	100.0 (64)
Cross-validation			
Males	64.1 (41)	35.9 (23)	100.0 (64)
Females	35.9 (23)	64.1 (41)	100.0 (64)

[a]Correct classification was performed on 64.8% of the original grouped cases.
[b]Cross-validation was performed only on the analysis cases, in which each case was classified by the functions derived from all other cases.
[c]Correct classification was performed on 64.1% of the cross-validated grouped cases.

Gender prediction does not represent a problem when a complete skeleton is found. However, decomposition would lead to the deterioration of soft tissues and the detachment of the mandible from the cranium. As a result, the cranium is disassociated from the rest of the body parts, and this phenomenon was reported to occur early in the disarticulation sequence of humans (27). Provided that only the cranium or mandible was found instead of a complete skull, this study formulated separate upper and lower arches gender prediction models. The standard deviation for each variable was found to be relatively small in this study contributed to higher confidence and validity in the recorded input data. Two prediction models were finally constructed by the stepwise discriminant analysis to simulate the forensic scenarios. It was based on the input from the upper arch dimensions, lower arch dimensions, and both upper and lower arch dimensions.

Upper inter-second premolar width and lower inter-molar width exhibited the most significant effect or ability to predict whether a randomly selected case was male or female. Thus, these variables made up the predictors in the model. Even though univariate analyses

Table IV: Discriminant function analysis for lower arch dimensions

Function	Variables	Discriminant function coefficients	Wilk's lambda	p	Group centroids	
					Males	Females
2	Lower inter-molar width	0.411	0.902	<0.001	0.327	-0.327
	(Constant)	-18.886				

indicated arch length and perimeter were also statistically significant between gender, there were not selected by stepwise procedure in the prediction models. Similar scenarios could be observed in gender prediction model using tooth sizes where stepwise method may select only few variables from a list of many variables that showed statistically significant different between gender (28,29).

Other researchers utilised intercanine width and ratio in formulating gender prediction models. Their study used mandibular canine index (MCI) with some modifications (6,7,17) while others (26,30,31) only reported univariate analyses findings. All these studies showed that dental arch dimensions are larger in males than in females. However, findings from univariate analyses of arch dimensions may have been overquoted for the accuracy of gender prediction and suitability for forensic application. So far, only few literatures reported prediction accuracy rates using dental arch dimension variables. Accuracy of MCI may varies from as high as 87.5% (6) to approximately moderate accuracy 66%-75% (17) and poor accuracy (32) while using arch width, Daniel et al. (16) reported 92% specificity and Okori et al. (10) only reported prediction models. At least to our knowledge, our study was the only one who reported both prediction accuracy rates and models. Accuracy rate is one of the attributes for any testimony related to technique/ scientific data to be admissible in court of law (33).

The percentage of grouped cases ranged from 64.1% to 67.2%. To be specific, the percentage of the original grouped cases, which was correctly classified with discriminant function (1), was slightly higher compared to that of the discriminant function (2). Similarly, the percentage of cross-validated grouped cases, which was correctly classified with discriminant function (1), was slightly higher than that of the discriminant function (2). Therefore, it could be concluded that the formula of the discriminant functions (1) and (2) were moderately strong and represented the simplified model for the gender determination of the upper and lower arches, respectively.

The findings of this study would enlighten forensic odontology work in identification process and facilitate reconstructive identification process. In the event where limited information available for gender estimation, this simple method may provide information act as an adjunct to the estimation process. The 2D method used will be practical because not all laboratory has a 3D scanner.

This study has its limitation due to only moderate accuracy prediction rates was obtained and the narrow age sample preclude the variation among subjects in their adulthood and late adulthood. Further studies may be designed to quantify the accuracy of gender estimation with wider age range samples.

CONCLUSION

A significant difference was found between genders in terms of the upper and lower arch dimensions, in which the dental arch dimensions were larger among the males compared to the females. Prediction models obtained in this study were moderately strong predictors which may be used as an adjunct to predict gender.

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REFERENCES

1. Astete JC, San Pedro VJ, Suazo GI. Sexual dimorphism in the tooth dimensions of Spanish and Chilean peoples. Int J Odontostomatol. 2009 July;3(1):47–50. Available from: http://www.ijodontostomatology.com/wp-content/uploads/2018/04/2009_v3n1_008.pdf
2. Vodanovic M, Brkic H. Dental Profiling in Forensic Science. Rad 514 Med Sci. 2012;38:153–63. doi: 10.21857/y6zolb3l1m
3. Pretty IA, Sweet D. A look at forensic dentistry - Part 1: The role of teeth in the determination of human identity. Br Dent J. 2001;190(7):359–66. doi: 10.1038/sj.bdj.4800972
4. Camps F, Robinson A, Lucas B, Gradwohl R. Gradwohl's Legal medicine. Bristol: Wright; 1976.
5. Saini V, Mehta M, Saini R, Shamal SN, Singh TB, Tripathi SK. Is north Indian population changing it craniofacial form? A study of secular trends in craniometric indices and its relation to sex and ancestry estimation. Forensic Sci Crimino. 2017;2(2):1–14. doi: 10.15761/FSC.1000115
6. Rao NG, Rao NN, Pai ML, Kotian MS. Mandibular canine index - A clue for establishing sex identity. Forensic Sci Int. 1989;42(3):249–54. doi: 10.1016/0379-0738(89)90092-3
7. Narang RS, Manchanda AS, Malhotra R, Bhatia HS. Sex determination by mandibular canine index and molar odontometrics: A comparative study. Indian J Oral Sci. 2014;5(1):16–20. doi: 10.4103/0976-6944.129944
8. Rocha MFN, Pinto PHV, Franco A, da Silva RHA. Applicability of the mandibular canine index for sex estimation: a systematic review. Egypt J Forensic Sci. 2022;12(1):1–18. doi: 10.1186/s41935-022-00270-w
9. Nojima K, McLaughlin RP, Isshiki Y, Sinclair PM. A Comparative Study of Caucasian and Japanese Mandibular Clinical Arch Forms. Angle Orthod. 2001;71(3):195–200. doi: 10.1043/0003-

3219(2001)071<0195: ACSOCA>2.0.CO;2
10. Okori H, Apolot PS, Mwaka E, Tumusiime G, Buwembo W, Munabi IG. A secondary analysis to determine variations of dental arch measurements with age and gender among Ugandans Oral Health. BMC Res Notes. 2015;8(1):428. doi: 10.1186/s13104-015-1411-6
11. Nummikoski P, Prihoda T, Langlais RP, McDavid WD, Welander U, Tronje G. Dental and mandibular arch widths in three ethnic groups in Texas: A radiographic study. Oral Surgery, Oral Med Oral Pathol. 1988;65(5):609–17. doi: 10.1016/0030-4220(88)90146-6
12. Merz ML, Isaacson RJ, Germane N, Rubenstein LK. Tooth diameters and arch perimeters in a black and a white population. Am J Orthod Dentofac Orthop. 1991;100(1):53–8. doi: 10.1016/0889-5406(91)70049-3
13. Raberin M, Laumon B, Martin JL, Brunner F. Dimensions and form of dental arches in subjects with normal occlusions. Am J Orthod Dentofac Orthop. 1993;104(1):67–72. doi: 10.1016/0889-5406(93)70029-N
14. Omar H, Alhajrasi M, Felemban N, Hassan A. Dental arch dimensions, form and tooth size ratio among a Saudi sample. Saudi Med J. 2018;39(1):86–91. doi: 10.15537/smj.2018.1.21035
15. Dung TM, Nhu Ngoc VT, Khoi TD, Chu D-T, Dung DT, Khue LN, et al. The dental arch dimensions in Vietnamese children at 7 years of age, and their variation by gender and ethnicity. J Oral Biol Craniofacial Res. 2019;3(9):236–40. doi: 10.1016/j.jobcr.2019.06.004
16. Daniel MJ, Khatri M, Srinivasan SV, Jimsha VK, Marak F. Comparison of Inter-Canine and Inter-Molar Width as an Aid in Gender Determination: A Preliminary Study. J Indian Acad Forensic Med. 2014 Aug;36(2):168–72. Available from: https://indianjournals.com/ijor.aspx?target=ijor:jiafm&volume=36&issue=2&article=011
17. Gupta J, Daniel MJ. Crown size and arch width dimension as an indicator in gender determination for a Puducherry population. J Forensic Dent Sci. 2016;8(3):120–5. doi: 10.4103/0975-1475.195105
18. Cassidy KM, Harris EF, Tolley EA, Keim RG. Genetic influence on dental arch form in orthodontic patients. Angle Orthod. 1998;68(5):445–54. doi: 10.1043/0003-3219(1998)068%3C0445:giodaf%3E2.3.co;2
19. Hair JF, Black WC, Babin BJ, Anderson RE. Multivariate Data Analysis. New Jersey: Prentice Hall; 2006.
20. Harris EF. A longitudinal study of arch size and form in untreated adults. Am J Orthod Dentofac Orthop. 1997;111(4):419–27. doi: 10.1016/S0889-5406(97)80024-8
21. Alam MK, Shahid F, Purmal K, Ahmad B, Khamis MF. Tooth size and Dental arch Dimension measurement through Cone beam Computed Tomography: Effect of Age and Gender. Res J Recent Sci. 2014 Sept;3:85–94. Available from: www.isca.in
22. Leifert MF, Leifert MM, Efstratiadis SS, Cangialosi TJ. Comparison of space analysis evaluations with digital models and plaster dental casts. Am J Orthod Dentofac Orthop. 2009;136(1):16.e1-16.e4. doi: 10.1016/j.ajodo.2008.11.019
23. Sousa MVS, Vasconcelos EC, Janson G, Garib D, Pinzan A. Accuracy and reproducibility of 3-dimensional digital model measurements. Am J Orthod Dentofac Orthop. 2012;142(2):269–73. doi: 10.1016/j.ajodo.2011.12.028
24. Lewis AJ, Sreekumar C, Srikant N, Boaz K, Nandita KP, Manaktala N, et al. Estimation of age by evaluating the occlusal tooth wear in molars: A study on dakshina kannada population. Clin Cosmet Investig Dent. 2021;13:429–40. doi: 10.2147/CCIDE.S313587
25. Uysal T, Memili B, Usumez S, Sari Z. Dental and Alveolar Arch Widths in Normal Occlusion, Class II division 1 and Class II division 2. Angle Orthod. 2005;75(6):941–7. doi: 10.1043/0003-3219(2005)75[941:DAAAWI]2.0.CO;2
26. Kuntz TR, Staley RN, Bigelow HF, Kremenak CR, Kohout FJ, Jakobsen JR. Arch widths in adults with class I crowded and class III malocclusions compared with normal occlusions. Angle Orthod. 2008;78(4):597–603. doi: 10.2319/062507-294.1
27. Haglund WD, Reichert DG, Reay DT. Recovery of Decomposed and Skeletal Human Remains in the “Green River Murder” Investigation. Am J Forensic Med Pathol. 1990;11(1):35–43. doi: 10.1097/00000433-199003000-00004
28. Angadi P V., Hemani S, Prabhu S, Acharya AB. Analyses of odontometric sexual dimorphism and sex assessment accuracy on a large sample. J Forensic Leg Med. 2013;20(6):673–7. doi: 10.1016/j.jflm.2013.03.040
29. Khamis MF, Taylor JA, Malik SN, Townsend GC. Odontometric sex variation in Malaysians with application to sex prediction. Forensic Sci Int. 2014;234:183.e1-183.e7. doi: 10.1016/j.forsciint.2013.09.019
30. Hussein KW, Rajion ZA, Hassan R, Noor SNFM. Variations in tooth size and arch dimensions in Malay school children. Aust Orthod J. 2009 Nov;25(2):163–8. Available from: https://pubmed.ncbi.nlm.nih.gov/20043553/
31. Ling JYK, Wong RWK. Dental arch widths of Southern Chinese. Angle Orthod. 2009;79(1):54–63. doi: 10.2319/092007-452.1
32. Acharya AB, Mainali S. Limitations of the mandibular canine index in sex assessment. J Forensic Leg Med. 2009;16(2):67–9. doi: 10.1016/j.jflm.2008.08.005
33. Daubert v. Merrell Dow Pharmaceuticals, Inc. 509 U.S. 579.1993 June. Available from: https://supreme.justia.com/cases/federal/us/509/579/