Palatal Geometry as a Forensic Evidence for Sex Estimation

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Abstract:

Aim: Sex estimation from the palatal width and length dimensions for biometric analysis of forensic cases.

Materials and methods: For this research the width and length dimensions of 241 maxillary dental casts of 133 female and 108 male subjects with average age 22.57 weresimultaneously measuredusing vernier and sliding callipers, under the authorization of the ethical committee of the Rectorate of Kutahya Health Sciences University.The data were statistically analysed due to sex by IBM SPSS version 25.0 statistical software using; descriptive, regression, discriminant analyses and student t- test.

Results: In this research the correct classification rates between groups showed that 77.4% of females (103) and 79.6% of males (86) were correctly classified by Fisher's Linear Discriminant Functions (LDF). Totally 78.4% of cases were correctly classified due to sex.

Conclusion: Sexual dimorphism is possible from the palatal measurements of human remains.The width of the horizontal line connecting the distal contact points of second premolars and the length of the vertical line drawn from this horizontal line to the mesial contact points of central incisors were significant indicators.

Keywords: Sexual dimorphism, Palatal size, Personal identification, Forensic odontology, Anthropology.

Introduction:

The identification examinations of forensic odontology comprise the evaluation of; the face and head dimensions, maxillary inter canine arch width, various dimensions of teeth and palatal structures which shows considerable size differences that are sexually dimorphic and unique to the individual, both for adults and for children, despite all being independent factors[1,2,3,4,5]. Principally the diagnosis of sex has been mentioned as a key for the anthropological and forensic osteological analysis[6].

It is reported that the palatal structures appear in a human foetus in between the 6th and 8th weeks of intrauterine life[7]. Male palatal measurements were found higher than females even in this foetal period, as in a study conducted on the palatal development of 21 male and 19 female foetuses aged between 17th to 40th intrauterine period, the hard palatal length measurements were registered and compared, where the mean values of males were higher than the mean values of

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females for all male palatal measurements[8].Research on hard palatal dimensions showed that length in the sagittal plane was significant (p-value <0.01) in males and all linear variables were larger in adults than in adolescents[9]. It is claimed that among these dimensions some palatal measurements can be used as predictors of sex, especially the maxillary arch depth was recommended to be used as a tool for sex determination along with other biometric dimensions[10]. It was found that the males have a greater absolute size of the hard palate than do the females[11].

The importance of arch size, variation in human hard palate structures and all the measuring methods for the orthodontics, prosthetics, forensic dentistry and dental anthropology fields of dentistry have been focused on by researchers, and it was mentioned that all measuring methods showed sexual dimorphism in arch dimensions in a spectrum ranging from calliper measurements of plaster models to digital computer software measurements of dental models[12,13].

An important issue for forensic odonatological analysis is the resistance of examined tissues to factors such as; time, temperature and humidity changes which occur after death. The palatal structures and teeth which are preserved by cheeks, lips, tongue, bone and fat tissues are resistant to such factors and are accepted as reliable identification references[14]. The purpose of this study was to provide sexual dimorphism data from the width and length of Turkish young individuals' palatal dental arch structures to be used for forensic odontological identification studies.

Materials and methods:

In this study, the biometric measurements of 241 maxillary dental casts belonging to 133 female (55,1%) and 108 male (44,9%) volunteer dentate cases, within the age range of 20-25 (average age 22.6) were examined. The dental casts were prepared by pouring dental stone in alginate impression trays which were mixed according to the manufacturer's water/powder ratio.

Individuals with palate anomalies and others using prosthetic or orthodontic appliances were not included in this study. All dimensions taken along the medial-lateral axis of the dental arcade of hard palate were reported as "width" and measurements taken along the anterior-posterior axis of the dental arcade-palate region were termed as "length"[15].

The width and length of the dental casts were simultaneously measured by using two callipers in an overlapped position. For the width measurements, a vernier calliper with 0.01 mm accuracy and for the length measurements, an anthropological sliding calliper with 0.1 mm accuracy was used. The width dimensions of the dental casts were horizontally measured in millimetres in-between the distal contact points of each pair of anterior five teeth as; centrals, laterals, canine incisors, first and second premolars and synchronously the length dimensions of the dental casts were measured by using a sliding calliper starting from the mesial contact points of the central teeth, and measuring each length corresponding to each width between the above-mentioned tooth pairs given in a line order (Figure 1).

The width and length data were statistically analysed according to sex by IBM SPSS version 25.0 statistical software using; descriptive, regression, discriminant analyses and student t- test. Curve Expert Professional Programme was used to draw the palatal arch curves according to the minimum and maximum widths of male and female subjects (Figure 2). R Programming -a software for data calculation, analyses, and graphical demonstration- wasused to produce the overlapping graphics of male and female dental arch geometry (Figure 3).

Results:

The descriptive statistical analyses of palate width and length measurements according to sex in a line order in-between the distal contact points of each pair of anterior five teeth showed that in each measurement, the average width and length dimensions of the males were found to be larger than the females (Table 1). The difference of width and length measurements according to sex on the basis of line order was analysed by student t-test. The results showed that there was a significant difference in all dimensions (p-value<0.05), except the 1st line between the central teeth where p-value <0.06. This difference was demonstrated on the regression lines of extreme cases having minimum and maximum width dimensions due to length dimensions of females and males in Figure 2.

Quadratic regression models and their coefficients of determination (R-square values which is a statistical measure representing how much variation in the length measurements are explained by the width measurements)were created to reveal the characteristics of male and female palate geometry which were given below:

$Length_{Female} = -0.205 + 0.04 * Width^2_{Female}$ with $R^2=0.933$,
$Length_{Male} = 0.096 + 0.038 * Width^2_{Male}$ with $R^2=0.930$.

Scattered plots and fitted quadratic regression models for females and males representsa parabolic geometric design. These regression models for females and males and their superimposition show that the geometric shape of male palatal structure was larger than the females (Figure 3).

In order to reveal the differences in palate structures in terms of sex, seen in Figure 3, the width and length data were compared according to sex with two independent samples t-test. The discriminant analysis was applied to disclose whether the palatal measurements were significative to determine sex. The multi variate two group means were compared with Wilks' Lambda and found to be statistically significant p-value < 0,05 which means the variables differ due to sex. The order of the variables that create this difference is specified according to the structure matrix values. When the structure matrix values are ordered from largest to smallest, it shows that the largest value is the variable that contributes the most to sex determination. Here, the length and width of second premolar were the largest value found to be the most effective variables in determining sex (Table 2).

When it is necessary to determine the sex of an unidentified forensic case from the palatal measurements, a functional relationship should be used. For this aim classifications of Fisher's Linear Discriminant Functions (LDF) for female, male and for both were predicted as follows

$LDF_{Female}= -366{,}236 + 4{,}279*W_5 - 1{,}043* W_4 + 5{,}403* W_3 - 2{,}569*W_2 + 5{,}117*W_1 + 9{,}828*L_5 + 7{,}028*L_4 - 0{,}859*L_3 + 1{,}086*L_2 - 11{,}214*L_1$

$LDF_{Male}= -400{,}940 + 4{,}615*W_5 -1{,}123* W_4 + 5{,}442* W_3 - 2{,}630*W_2 + 5{,}103*W_1 + 10{,}969*L_5 + 6{,}655*L_4 - 1{,}193*L_3 + 2{,}236*L_2 - 12{,}488*L_1$

$LDF_{Both}= 34{,}704 - 0{,}336*W_5 + 0{,}08* W_4 - 0{,}039* W_3 + 0{,}061*W_2 + 0{,}014*W_1 - 1{,}141*L_5 + 0{,}373*L_4 + 0{,}334*L_3 - 1{,}15*L_2 + 1{,}274*L_1$

where W_i and L_i represent order of width and length measurements (i=1,2,3,4,5).

Classification results were determined by placing the width and length measurements of the individual in the predicted LDF functions, then the individual can be assigned to a group according to the classification rates defined below:

If $LDF_{Female} \geq LDF_{Male}$ or $LDF_{Both} \geq 0$, then the case is assigned to be female

If $LDF_{Female} < LDF_{Male}$ or $LDF_{Both} < 0$, then the case is assigned to be male.

In this research the correct classification rates between groups showed that 77.4% of females (103) and 79.6% of males (86) were correctly classified. Totally 78.4% of cases were correctly classified due to sex.

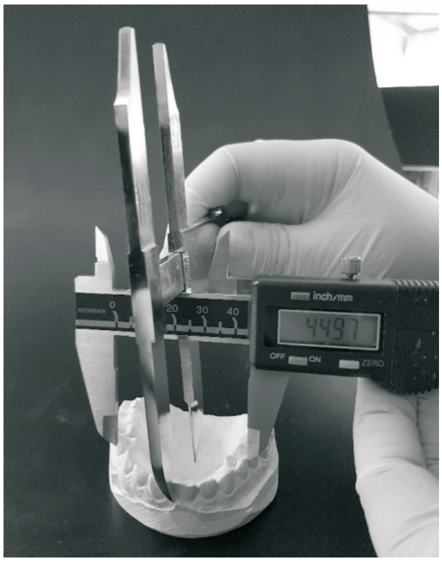

Table 1: Summary statistics of palate width and length measurements in millimetres, according to sex in a line order (horizontal measurements in-between the distal contact points of each pair of anterior five teeth).

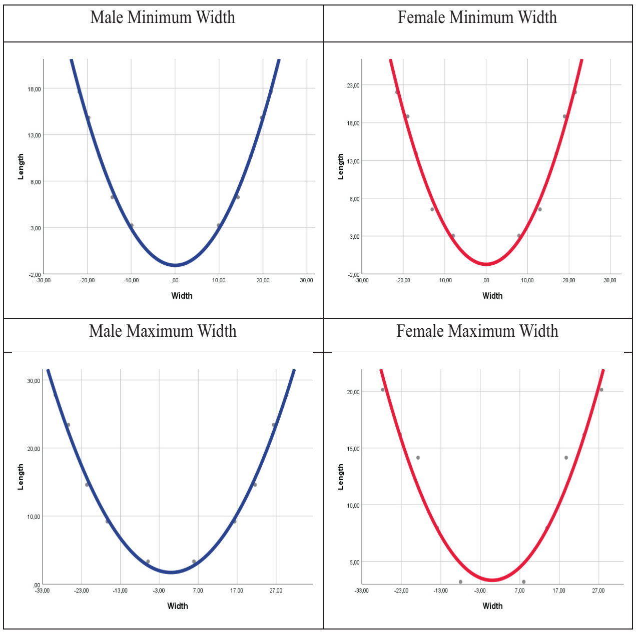

Table 2:Tests of equality of group means and the results of the structure matrix.

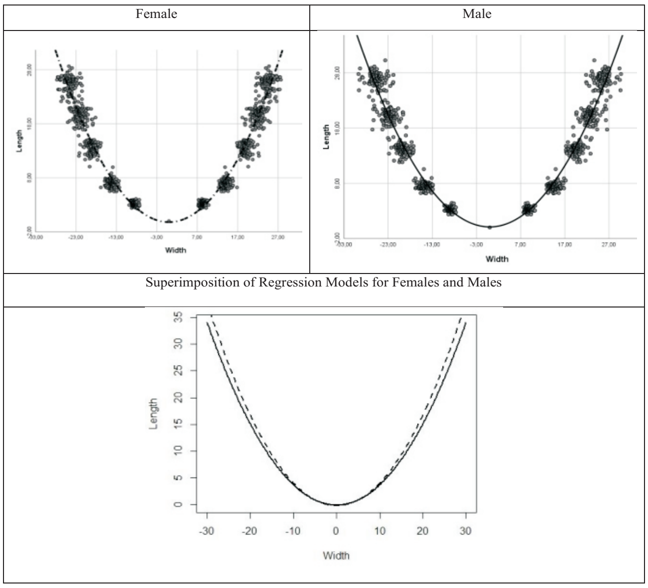

Figure 3: Scattered plots andregression models for females (dashed line) and males (straight line), and superimposition of regression models for females and males.

Table 1: Summary statistics of palate width and length measurements in millimetres, according to sex in a line order (horizontal measurements in-between the distal contact points of each pair of anterior five teeth).

Line Between	Descriptive Statistics	Female (n=133)		Male (n=108)	
		Width	Length	Width	Length
1. Santral Incisives	Minimum	14.60	2.27	15.34	2.36
	Maximum	19.64	4.10	20.60	4.43
	Mean	**17.01**	**3.18**	**17.56**	**3.28**
	Std. Dev.	1.04	0.43	1.12	0.40
2. Lateral Incisives	Minimum	24.54	5.46	25.82	6.17
	Maximum	33.68	9.97	34.38	10.56
	Mean	**28.30**	**6.94**	**29.27**	**7.49**
	Std. Dev.	1.59	1.41	2.07	1.49
3. Canines	Minimum	33.64	10.07	34.52	10.56
	Maximum	44.50	18.09	45.62	18.16
	Mean	**38.05**	**13.59**	**39.32**	**14.17**
	Std. Dev.	1.94	2.60	2.26	2.58
4. First Premolars	Minimum	36.30	15.78	39.20	16.19
	Maximum	50.02	25.47	53.12	26.06
	Mean	**43.88**	**19.56**	**45.69**	**20.28**
	Std. Dev.	2.35	3.01	2.67	3.01
5. Second Premolars	Minimum	43.00	20.62	43.62	23.02
	Maximum	55.36	28.66	59.42	30.26
	Mean	**49.08**	**25.36**	**51.32**	**26.87**
	Std. Dev.	2.59	3.24	3.00	3.55

Table 2:Tests of equality of group means and the results of the structure matrix.

Dimension	Line Order	Structure Matrix	Wilks' Lambda	F	df_1	df_2	Sig.
Width	5	**0.53**	0.86	38.89	1	239	0.00
	4	0.47	0.88	31.25	1	239	0.00
	3	0.39	0.92	21.25	1	239	0.00
	2	0.33	0.94	15.60	1	239	0.00
	1	0.33	0.94	14.93	1	239	0.00
Length	5	**0.73**	0.76	73.83	1	239	0.00
	4	0.37	0.93	19.34	1	239	0.00
	3	0.35	0.93	17.47	1	239	0.00
	2	0.49	0.88	34.28	1	239	0.00
	1	0.16	0.99	3.70	1	239	0.06

Discussion:

During forensic identification studies, sex determination from osteometric and odontometric morphological analysis is possible[16]. It is reported that palate structures as one of the diagnostic features of sex in the skull which is more likely to be larger, wider, and U-shaped in males, and smaller and parabolic in females depending on the length of the cheek tooth row[17,18]. Research performed on 176 crania of known sex by three-dimensional geometric morphometric technique revealed that there were shape differences between sexes where in males the palate was found as the deepest and more elongated and the importance of these results were emphasized from the view of bioarchaeological and of forensic examinations[19].

It is stated that the loss of teeth may affect the study of morphological dimorphism using the palate shape as a diagnostic indicator[6] and it is also reported that the palate structures may lose its features in edentulous cases and/or cases causing friction due to prosthetic or orthodontic appliances[20]. Therefore, in this study, the shape and dimensions of the palate structures of healthy, mature, young individuals, average age 22.6, having dentulous arches were preferred as subjects.

In a study on mathematical analysisof dental arch form and size it was recommended to replace plaster model analysis with indirect 3-D models produced by scanning tools and computer imaging techniques for measuring and mathematical modelling of the tooth and dental arch sizes[21].

Considering that each method has its own advantages and disadvantages, in this study it was preferred to conduct the analyses directly on plaster models.

Research performed on the length and breadth dimensions of the hard palates of 125 skulls of 90% Bantu and 10%Nilo-Hamitic Kenya individuals showed that, the mean palatal length of Kenyan sample was 4.92 cm and the width of the palate, revealed that 43% of the skulls had a narrow palate, 24% had an intermediate palate, and 33% had a wide palate. Where the females had narrow and intermediate palates in 91 percent of cases, compared to 64 percent of males[22]. In this research the average width and length dimensions of the males were found to be larger than the females for each measurement, which was found to be statistically significant (p-value < 0,05), and the length and width dimensions in line with the second premolars were shown to be the most efficient criteria in predicting sex. A functional connection, Fisher's linear discriminant functions classifications were created for females, males, and both to establish the sex of an unidentified forensic case from the palatal dimensions. Using this correlation, the correct classification rates between groups were calculated which showed that 77.4% of females (103) and 79.6% of males (86) were correctly classified. Totally 78.4% of cases were correctly classified due to sex.

Conclusion:

The following results were derived from this research:

1. Palatal width and length size variables differ due to sex (p-value < 0,05) whichcan be used as an auxiliary data for sex determination of forensic identification procedures.In this research the correct classification rates between groups showed that 77.4% of females (103) and 79.6% of males (86) were correctly classified. Totally 78.4% of cases were correctly classified due to sex.
2. These regression models for females and males and their superimposition show that the geometric shape of male palatal structure was larger than the females. The length and width dimensions in line with the second premolars were the most effective variables in determining sex.
3. Scattered plots and fitted quadratic regression models for female and male palatal structures represent a parabolic geometric design.

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