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Original Article

Correlation coefficients for predicting canine diameters from premolar and molar sizes

María Hilary Zúñiga [a], Joan Viciano [b], Gabriel Mario Fonseca [c], Carolina Soto-Álvarez [c], Javier Rojas-Torres [c], Sandra López-Lázaro [a,c*]

[a] Departamento de Antropología, Facultad de Ciencias Sociales, Universidad de Chile, Chile
[b] Operative Unit of Anthropology, Department of Medicine and Ageing Sciences, 'G. d'Annunzio' University of Chieti—Pescara, Chieti, Italy
[c] Forensic Dentistry Lab, Centro de Investigación en Odontología Legal y Forense —CIO—, Facultad de Odontología, Universidad de La Frontera, Chile

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Abstract *Background/purpose:* The permanent canine is the most widely used tooth for sex estimation because it is the tooth with the highest degree of sexual dimorphism; however, there are several factors that can limit the analysis (e.g., pathologies, postmortem loss). The aim of this work was to analyse the correlation between the dimensions of the canines and those of the premolars and molars, and evaluate the correspondence of real and predicted canine dimensions by applying the equations developed.
Materials and methods: The sample was composed of digital models of 80 adult individuals from Temuco, Chile. The buccolingual and mesiodistal diameters of the canine, premolar and molar dental crowns were measured and Pearson's linear regression analysis was performed in order to determine the correlation between the diameters. The equations obtained from the reference subsample were applied to a validation subsample to predict canine dimensions from the dimensions of the postcanine teeth.
Results: Four regression equations were obtained, all for prediction of the size of the lower canines, whose correlation coefficient ranged from 0.701 to 0.738. The regression equations developed with the reference sample were tested on the validation sample using a Student's t-test for paired samples and the intraclass correlation coefficient. The differences between actual dental size and that predicted by the equations were not significantly different, and concordance analysis showed a moderate degree (0.485—0.585).
Conclusion: There is a limited correlation of canine dimensions with respect to premolars and

* Corresponding author. Departamento de Antropología, Facultad de Ciencias Sociales, Universidad de Chile, Forensic Dentistry Lab, Centro de Investigación en Odontología Legal y Forense —CIO—, Facultad de Odontología, Universidad de La Frontera, Chile.
E-mail addresses: sandra.lopez.l@ufrontera.cl, sanlopez@uchile.cl (S. López-Lázaro).

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molars. The correspondence between the actual and predicted canines dimensions is moderate.
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Introduction

Sexual dimorphism has been a subject of great interest in the scientific literature due to its analysis of the differentiation of biological sex between individuals.[1] The techniques most used in the evaluation of sex in the human skeleton have mainly focused on the pelvis and skull,[2] and on the long bones;[3] however, numerous studies have identified dimorphic characteristics in human dentition.[4–7] In the study of permanent dentition, the canine is considered the tooth that presents the highest degree of sexual dimorphism; that of the male is larger than that of the female.[8,9] Its analysis as a key tooth for the estimation of sex is based on the measurement of its dimensions through dental techniques.[10]

Despite the advantages presented by the canine for the study of sexual dimorphism, there are a number of limitations associated with its postmortem loss, as well as pathologies and other limiting factors. Being a monoradicular tooth, its postmortem loss is more frequent[11] than that of multi-root posterior dentition in the alveoli.[12] In addition, along with the incisors, canines are the teeth most affected by enamel hypoplasia;[13] and, with the third molars, the ones that are most frequently impacted.[14]

To this is added that, despite the numerous articles published in the scientific literature for the evaluation of sexual dimorphism in permanent dentition,[4–6,9,15,16] many investigations have focused exclusively on the dimensions of the canine for the diagnosis of sex,[17–20] which limits the development and application of prediction methods to this tooth. The development of estimation methods by measuring the rest of the dentition expands their applicability; however, if there are equations exclusively for the canine, the rest of the teeth cannot be analysed.

Recently, Viciano and Tanga[12] carried out a study on an Italian archaeological population, demonstrating that the size of the permanent canines can be estimated with high precision using the dimensions of the posterior teeth (premolars and molars), so that the predicted values for the canines could be used with great reliability for estimation of the sex of bone remains by applying specific functions developed for them.

Therefore, the objective of this work is (1) to analyse the correlation of the dimensions of the permanent canines with respect to premolars and molars by developing linear regression equations, and (2) to assess the correspondence between the real and predicted values for the canines by applying the different equations developed.

Material and method

Study sample and acquisition of 3D digital models

The sample was composed of digital models of 80 adult student individuals from the University of La Frontera, Temuco, Chile. Of these, 1365 permanent teeth that correspond to canines, premolars and molars were occupied. This study was approved by the Scientific Ethical Committee of the University of La Frontera, with code 031_2017.

Prior to scanning of the dentition, its suitability for inclusion in the present study was evaluated, taking into account the following exclusion criteria: teeth with morbid processes that involve malformation defects (abnormalities of shape, volume or structure, such as enamel hypoplasia, amelogenesis imperfecta) or acquired losses of coronary substance (for example: caries, fractures, erosions, abrasions); teeth with rehabilitations of more than a third of the dental volume or that involve the dental measurement points; dental arches with crowding that prevent intraoral scanner readings.

The 3D models were obtained using a Condor intraoral scanner (Condor Scan, Gent, Belgium). The scanner technique is based on a video and photogrammetry system that creates a digital 3D model of the person's oral cavity with an accuracy of 30 microns.

Dental measurements

Through use of the Landmark Editor program (US version 3.6), the buccolingual (BL) and mesiodistal (MD) diameters of the canine, premolar and molar dental crowns were measured (the third molar was excluded from the study), both maxillary and mandibular on the left side. The BL diameter of the crown is defined as the maximum distance between two parallel planes, one tangential to the most lingual/palatine point on the side of the crown, and the other tangential to a point on the buccal/labial side of the crown.[21] The MD diameter of the crown is defined as the distance between the points of contact of the crown of a tooth with its contiguous ones, in normal occlusion.[22] In canines, the maximum distance between two parallel planes and the distance between the contact points of the crown of the tooth with its neighbours are the same.[21–23] However, in premolars and molars, the contact points may not coincide with the maximum protuberance of the sides of the mesial and distal crown.[24]

Statistical analysis of the data

First, the final sample was subdivided into two subsamples: a reference subsample consisting of 60 individuals (corresponding to 75% of the individuals in the sample), and a validation subsample consisting of the remaining 20 individuals (25% of the sample).

In the first instance, for the reference subsample, descriptive statistical analysis was performed for each tooth, obtaining the values of the sample size, mean, standard deviation and minimum and maximum values for each dental diameter. The assumptions of normality (Kolmogorov–Smirnov test), homoscedasticity (correlation of residues and predicted values) and independence (Durbin–Watson test) of each of the dental diameters were checked. Next, different regression models (e.g., linear, quadratic, cubic, power, exponential or logarithmic) were checked to select the best-fit model for prediction. Evaluating the coefficient of determination, no nonlinear model provided a better fit than the linear model. Thus, the linear simple and multiple regression were chosen as the best prediction model. Next, Pearson's linear regression analysis was performed in order to determine the correlation between canine diameters and premolar and molar diameters. The correlation analysis was performed by separating the maxillary and mandibular teeth. First, correlation of canine diameters with the diameters of the remaining teeth (premolars and molars) was analysed; that is, the correlation between two variables was evaluated: the canine MD or BL diameter with the MD or BL diameter of premolars or molars. Next, correlation between canine diameters and the combination of two or three diameters (either MD or BL) of premolars and molars, that is, three or four variables, respectively, was analysed. Finally, diagnostic plots were performed to check if the regression models worked well for the data. Normal Q–Q plots were used to assess if the residuals were normally distributed. Residual plots were performed to assess the appropriateness of the linear models.

In order to quantify the concordance and reproducibility of the observations, the data were analysed using the intraclass correlation coefficient (ICC). To evaluate the interobserver error, a subsample of 20 randomly selected individuals was chosen to perform the same measurements by the main observer (MHZ). The second observer (SLL) performed the same measurements at different times to the first observer in order to evaluate the interobserver error. Interpretation of the ICC values was carried out using the classification proposed by Fleiss [25], which defines the degree of agreement as: < 0.4 = poor reliability; 0.4–0.75 = moderate reliability; and >0.75 = excellent reliability.

Finally, the equations obtained from the reference subsample were applied to the validation subsample to predict the dimensions of the canines from the dimensions of the posterior teeth. To quantify the difference between the actual dimensions of the canines and those predicted by the different regression equations developed, a Student's t-analysis was carried out for paired samples and the ICC following the same interpretation criteria mentioned above.

All statistical analyses were performed with the statistical package IBM SPSS Statistics v 25 (IBM Corp., Armonk, N.Y., USA).

Results

The results of the intraobserver error analysis show an excellent degree of agreement between the observations. The ICC value for the MD dimension varies between 0.960 and 0.995, while for the BL dimension it shows a range of 0.980–0.997 (Table 1). Similarly, the results of the interobserver error analysis show an excellent degree of agreement. The ICC value for the MD dimension varies between 0.958 and 0.984, while for the BL dimension it shows a range of 0.952–0.994 (Table 2).

Table 3 shows the descriptive results for the total sample. Table 4 shows the regression equations for predicting

Table 1 Intra-observer agreement.

	Upper								Lower							
	N	Measure 1		Measure 2		Diff	ICC	AV	N	Measure 1		Measure 2		Diff	ICC	AV
		Mean	SD	Mean	SD					Mean	SD	Mean	SD			
MD																
C	19	7.901	0.593	7.987	0.543	−0.086	0.984	Exc	20	6.866	0.585	6.882	0.549	−0.016	0.983	Exc
PM1	20	7.170	0.550	7.175	0.570	−0.004	0.980	Exc	20	7.020	0.589	6.984	0.608	0.017	0.986	Exc
PM2	20	6.721	0.442	6.704	0.484	0.017	0.960	Exc	20	7.102	0.537	7.095	0.538	0.007	0.984	Exc
M1	20	10.274	0.596	10.207	0.617	0.067	0.987	Exc	16	10.845	0.836	10.843	0.820	0.003	0.995	Exc
M2	6	9.303	0.495	9.255	0.351	0.048	0.948	Exc	13	10.304	0.804	10.273	0.742	0.031	0.992	Exc
BL																
C	19	8.481	0.506	8.525	0.475	−0.044	0.983	Exc	20	7.766	0.539	7.692	0.534	0.074	0.983	Exc
PM1	20	9.770	0.803	9.771	0.798	−0.001	0.992	Exc	20	8.265	0.710	8.235	0.731	0.030	0.994	Exc
PM2	20	9.846	0.933	9.839	0.984	0.007	0.997	Exc	20	8.819	0.614	8.832	0.627	−0.013	0.986	Exc
M1	20	11.532	0.635	11.507	0.615	0.024	0.989	Exc	16	10.516	0.619	10.500	0.661	0.015	0.980	Exc
M2	6	11.373	0.529	11.342	0.569	0.031	0.985	Exc	11	10.306	0.899	10.242	0.834	0.064	0.996	Exc

N, number of individuals; Mean, overall measurement mean; SD, standard deviation; Diff, mean value of the difference between repeated measures; ICC, intraclass correlation coefficient; AV, agreement value; Exc, excellent; MD, mesiodistal; BL, buccolingual; C, canine; PM1, first premolar; PM2, second premolar; M1, first molar; M2, second molar.

Table 2 Inter-observer agreement.

	Upper							Lower						
	N	Measure 1		Measure 2		Diff	ICC	AV	N	Measure 1		Measure 2		Diff	ICC	AV
		Mean	SD	Mean	SD					Mean	SD	Mean	SD			
MD																
C	19	7.901	0.593	7.837	0.573	0.064	0.981	Exc	20	6.866	0.585	6.825	0.601	0.041	0.983	Exc
PM1	20	7.170	0.550	7.179	0.580	−0.009	0.967	Exc	20	7.020	0.589	7.046	0.576	−0.026	0.973	Exc
PM2	20	6.721	0.442	6.727	0.454	−0.006	0.958	Exc	20	7.102	0.537	7.029	0.469	0.073	0.979	Exc
M1	20	10.274	0.596	10.171	0.575	0.103	0.981	Exc	16	10.845	0.836	10.832	0.795	0.013	0.987	Exc
M2	6	9.303	0.495	9.598	0.596	−0.295	0.962	Exc	13	10.304	0.804	10.278	0.751	0.026	0.984	Exc
BL																
C	19	8.481	0.506	8.490	0.490	−0.009	0.975	Exc	20	7.766	0.539	7.788	0.576	−0.022	0.976	Exc
PM1	20	9.770	0.803	9.699	0.823	0.071	0.988	Exc	20	8.265	0.710	8.258	0.710	0.007	0.983	Exc
PM2	20	9.846	0.933	9.842	0.929	0.004	0.994	Exc	20	8.819	0.614	8.820	0.568	−0.001	0.988	Exc
M1	20	11.532	0.635	11.481	0.589	0.051	0.985	Exc	16	10.516	0.619	10.303	0.636	0.213	0.952	Exc
M2	6	11.373	0.529	11.291	0.509	0.082	0.981	Exc	11	10.306	0.899	10.262	0.891	0.044	0.971	Exc

N, number of individuals; Mean, overall measurement mean; SD, standard deviation; Diff, mean value of the difference between repeated measures; ICC, intraclass correlation coefficient; AV, agreement value; Exc, excellent; MD, mesiodistal; BL, buccolingual; C, canine; PM1, first premolar; PM2, second premolar; M1, first molar; M2, second molar.

the dimensions of the canines from the dimensions of the posterior teeth (premolars and molars). Only those equations that had a correlation coefficient greater than or equal to 0.7 were selected. Four regression equations were obtained, all for prediction of the size of the lower canines (Eq. (1)-Eq. (4)). The correlation coefficient ranges from 0.701 to 0.738. The coefficient of determination varies between 0.491 and 0.544. The highest correlation coefficient was found for the equation that predicts the MD diameter of the lower canines from the MD diameter of the first and second premolars ($r = 0.738$). Only Eq. (2) includes a BL dimension, specifically for the second lower premolar. Fig. 1 shows the Q—Q plots for the four multiple linear regression equations developed, where the data points closely follow the straight line at 45° angle upwards (left to right). This confirms that the residuals are normally distributed. Fig. 2 shows the residual plots, where the residuals are randomly dispersed around the horizontal axis, and therefore the linear regression models are appropriate for the data. These plots confirm that the development of nonlinear regression models is not necessary.

The multiple linear regression equations have the following form:

$$y = b_0 + b_1x_1 + b_2x_2 + \ldots + b_nx_n$$

where y is the predicted value of the dependent variable, x_1 to x_n are n distinct independent or predictor variables, b_0 is the y-intercept, and b_1 to b_n are the estimated regression coefficients.

According to the data of Table 4, the multiple linear regression equations are constructed as follows:

$$\text{LC MD} = 1.676 + (0.480 \times \text{LPM1 MD}) + (0.163 \times \text{LM1 MD}) \quad \text{Eq1}$$

Table 3 Descriptive analysis for total sample size.

	Upper					Lower				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
MD										
C	73	7.796	0.531	6.56	8.92	76	6.849	0.455	5.89	7.95
PM1	76	7.146	0.533	6.01	8.33	75	7.089	0.507	5.99	8.26
PM2	78	6.741	0.469	5.70	7.82	75	7.138	0.464	6.01	8.23
M1	74	10.234	0.626	8.62	11.55	69	10.846	0.680	9.40	12.43
M2	38	9.749	0.675	8.47	11.42	53	10.526	0.742	8.67	11.95
BL										
C	70	8.416	0.579	7.18	9.59	75	7.677	0.546	6.66	9.07
PM1	76	9.792	0.694	8.21	11.20	74	8.292	0.621	7.04	9.81
PM2	78	9.751	0.771	7.54	11.49	75	8.800	0.543	7.56	9.95
M1	74	11.516	0.653	10.13	12.81	67	10.683	0.579	9.45	12.15
M2	41	11.444	0.585	10.29	12.75	48	10.445	0.728	8.66	11.93

N, number of individuals; Mean, overall measurement mean; SD, standard deviation; Min, minimum value; Max, maximum value; MD, mesiodistal; BL, buccolingual; C, canine; PM1, first premolar; PM2, second premolar; M1, first molar; M2, second molar.

Table 4 Regression equation parameters.

Diameter to estimate	Equation	Model	Estimator	SE	95% confidence interval		t	Sig.	r	r^2
					Lower	Upper				
UC MD	—	—	—	—	—	—	—	—	—	—
LC BL	—	—	—	—	—	—	—	—	—	—
LC MD	Eq. (1)								0.714	0.510
		Constant	1.676	0.794	0.078	3.273	2.112	0.040		
		LPM1 MD	0.480	0.092	0.296	0.665	5.235	0.000		
		LM1 MD	0.163	0.067	0.028	0.298	2.433	0.019		
	Eq. (2)								0.701	0.491
		Constant	2.270	0.779	0.692	3.848	2.913	0.006		
		LPM1 MD	0.420	0.098	0.222	0.618	4.289	0.000		
		LM2 MD	0.153	0.069	0.014	0.292	2.225	0.032		
	Eq. (3)								0.707	0.499
		Constant	1.916	0.772	0.366	3.466	2.483	0.016		
		LPM1 MD	0.544	0.097	0.349	0.739	5.597	0.000		
		LPM2 BL	0.125	0.085	−0.045	0.296	1.474	0.147		
	Eq. (4)								0.738	0.544
		Constant	1.426	0.818	−0.222	3.073	1.744	0.088		
		LPM1 MD	0.539	0.110	0.316	0.762	4.878	0.000		
	—	LPM2 MD	−0.001	0.126	−0.256	0.253	−0.011	0.991		
		LM1 MD	0.150	0.073	0.003	0.297	2.053	0.046		
UC BL	—	—	—	—	—	—	—	—	—	—

SE, standard error; t, Student's t-test; Sig., significance; r, coefficient of correlation; r^2, coefficient of determination; LC, lower canine; UC, upper canine; LPM1, lower first premolar; LPM2, lower second premolar; LM1, lower first molar; LM2, lower second molar.

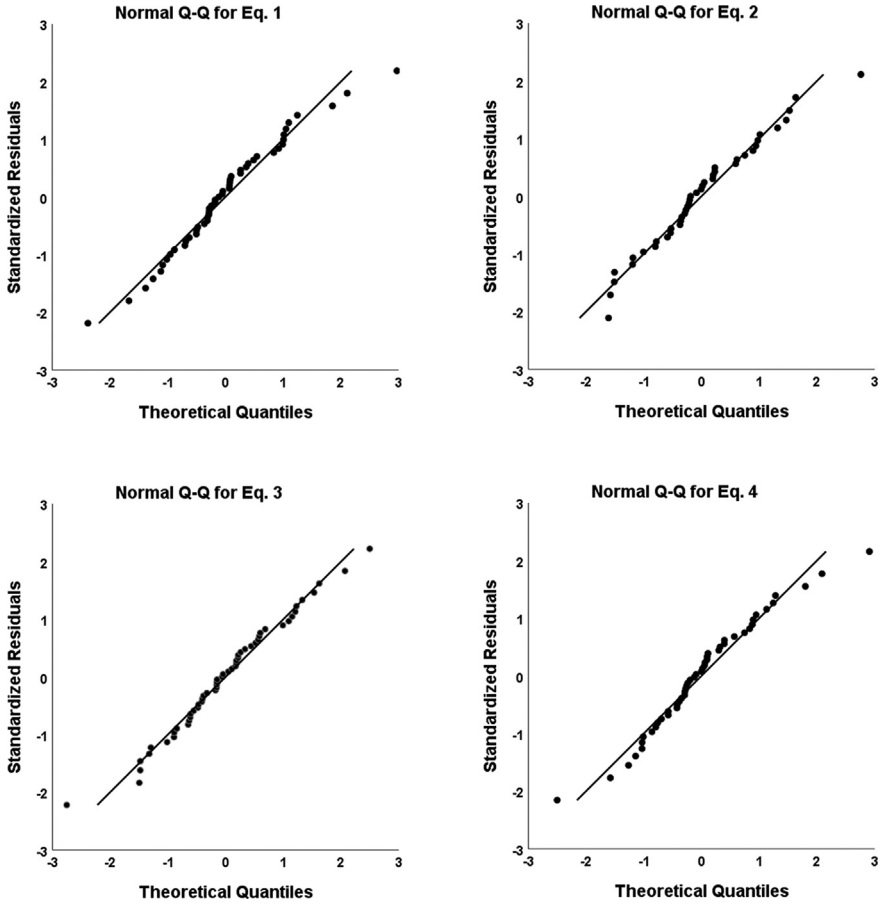

Fig. 1 Q–Q plots for the four multiple linear regression equations to assess if the set of residuals are normally distributed.

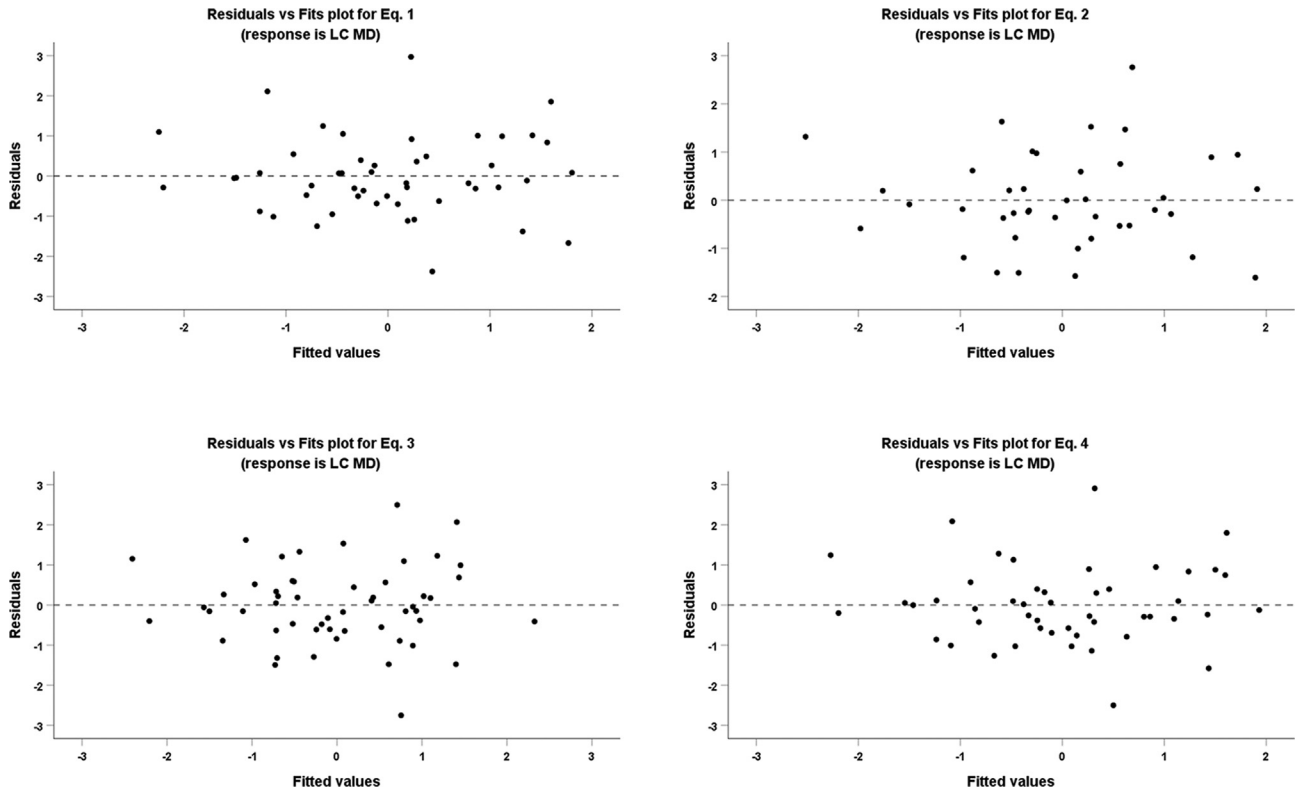

Fig. 2 Residuals vs fits plots to assess if the four multiple linear regression models are appropriate for the data.

$$\text{LC MD} = 2.270 + (0.420 \times \text{LPM1 MD}) + (0.153 \times \text{LM2 MD}) \quad \text{Eq2}$$

$$\text{LC MD} = 1.916 + (0.544 \times \text{LPM1 MD}) + (0.125 \times \text{LPM2 BL}) \quad \text{Eq3}$$

$$\text{LC MD} = 1.426 + (0.539 \times \text{LPM1 MD}) - (0.001 \times \text{LPM2 MD}) + (0.150 \times \text{LPM1 MD}) \quad \text{Eq4}$$

The four regression equations developed with the reference sample were tested on the validation sample (Table 5). Analysis of the differences between the values of the actual dental size and those predicted by the equations are not significantly different ($p > 0.05$; Table 6). The degree of agreement resulting after concordance analysis by the ICC is moderate, with values ranging from 0.485 to 0.585 (Table 7).

Discussion

The results for prediction of canine size in the present work show a weak correlation in relation to the size of premolars and molars. An acceptable correlation value has been found only for the MD diameter of the lower canine from the MD diameter of premolars and molars and the BL diameter of the second lower premolar. The rest of the combinations performed show lower correlation values ($r < 0.700$). The prediction of canine size obtained with the validation sample and the degree of moderate agreement obtained with the different equations are related to a discrete correlation value, resulting from the regression analysis.

Numerous studies in clinical dentistry have analysed the relationship between the size of unerupted canines and other teeth of mixed dentition.[26–29] However, this application is practically non-existent in the context of dental anthropology,[12] despite its usefulness in predicting the size of teeth to make different types of estimate in reconstruction of the biological profile, for example estimation of sex or ancestry. In the anthropological context, either archaeological or forensic, it is often impossible to make some key observations for the study of individuals due to the absence of teeth (antemortem or postmortem loss) or because they are affected by limiting factors (for example: caries, hypoplasia, fractures). This absence can reduce the application of certain methods, so that the development of others that allow prediction expands the possibilities of their being employed.

Despite numerous studies in clinical dentistry, the specific needs of studies in dental anthropology limit their application in this field. The most widely used methods of prediction in orthodontics are those of Moyers[27] and Tanaka & Johnston.[30] Both methods take dental segments, so the prediction provided is not for a tooth individually. As we have previously pointed out, the impediment to making observations in the anthropological context is frequent, so that application of methodology that requires the preservation of several teeth for determining variables is not always possible. In addition, these methods developed in clinical dentistry offer as a result prediction of the size of the canine-premolar segment,[27,28] a study variable that is

Table 5 Application of the regression equations applied to validation subsample.

Ind	Real LC MD	Eq	Estimated LC MD	95% CI (mm)		Ind	Real LC MD	Eq	Estimated LC MD	95% CI (mm)	
				Lower	Upper					Lower	Upper
008	7.24	Eq. (1)	7.05	2.55	11.55	052	7.10	Eq. (1)	7.14	2.62	11.67
		Eq. (2)	–	–	–			Eq. (2)	–	–	–
		Eq. (3)	7.04	2.48	11.60			Eq. (3)	7.06	2.60	11.54
		Eq. (4)	7.07	0.19	13.94			Eq. (4)	7.18	0.28	14.06
009	7.17	Eq. (1)	7.17	2.64	11.71	053	7.74	Eq. (1)	–	–	–
		Eq. (2)	7.09	2.52	11.66			Eq. (2)	7.22	2.53	11.91
		Eq. (3)	7.21	2.59	11.85			Eq. (3)	7.18	2.58	11.78
		Eq. (4)	7.21	0.25	14.17			Eq. (4)	–	–	–
010	7.04	Eq. (1)	6.46	2.26	10.66	054	6.11	Eq. (1)	6.34	2.23	10.46
		Eq. (2)	6.45	2.25	10.65			Eq. (2)	–	–	–
		Eq. (3)	6.46	2.21	10.71			Eq. (3)	6.39	2.20	10.59
		Eq. (4)	6.44	−0.02	12.90			Eq. (4)	6.33	0.18	12.46
016	7.58	Eq. (1)	6.93	2.55	11.30	055	6.75	Eq. (1)	7.20	2.68	11.73
		Eq. (2)	–	–	–			Eq. (2)	–	–	–
		Eq. (3)	6.99	2.56	11.43			Eq. (3)	7.33	2.64	12.03
		Eq. (4)	6.97	0.32	13.61			Eq. (4)	7.26	0.36	14.15
019	5.91	Eq. (1)	6.33	2.20	10.46	062	7.00	Eq. (1)	7.15	2.65	11.67
		Eq. (2)	6.29	2.20	10.39			Eq. (2)	–	–	–
		Eq. (3)	6.31	2.16	10.47			Eq. (3)	7.22	2.61	11.85
		Eq. (4)	6.30	0.23	12.38			Eq. (4)	7.20	0.40	13.99
025	6.44	Eq. (1)	–	–	–	064	7.38	Eq. (1)	6.87	2.48	11.26
		Eq. (2)	–	–	–			Eq. (2)	–	–	–
		Eq. (3)	7.22	2.63	11.82			Eq. (3)	6.70	2.49	10.92
		Eq. (4)	–	–	–			Eq. (4)	6.88	0.05	13.71
029	6.48	Eq. (1)	6.70	2.40	11.01	068	6.94	Eq. (1)	6.76	2.49	11.04
		Eq. (2)	6.64	2.34	10.93			Eq. (2)	6.91	2.44	11.38
		Eq. (3)	6.71	2.36	11.06			Eq. (3)	6.97	2.46	11.49
		Eq. (4)	6.71	0.19	13.22			Eq. (4)	6.80	0.19	13.39
031	6.68	Eq. (1)	6.42	2.26	10.59	077	6.61	Eq. (1)	6.91	2.49	11.34
		Eq. (2)	–	–	–			Eq. (2)	6.87	2.42	11.32
		Eq. (3)	6.50	2.20	10.80			Eq. (3)	6.84	2.46	11.22
		Eq. (4)	6.41	−0.02	12.83			Eq. (4)	6.93	0.31	13.54
043	–	Eq. (1)	–	–	–	079	6.01	Eq. (1)	6.39	2.25	10.53
		Eq. (2)	–	–	–			Eq. (2)	6.58	2.26	10.90
		Eq. (3)	–	–	–			Eq. (3)	6.38	2.25	10.53
		Eq. (4)	–	–	–			Eq. (4)	6.38	0.03	12.72
045	5.89	Eq. (1)	6.53	2.34	10.72	082	6.25	Eq. (1)	6.91	2.51	11.31
		Eq. (2)	6.56	2.31	10.81			Eq. (2)	7.06	2.45	11.68
		Eq. (3)	6.69	2.30	11.08			Eq. (3)	6.90	2.49	11.32
		Eq. (4)	6.54	0.35	12.72			Eq. (4)	6.93	0.21	13.65

Ind, individual; LC, lower canine; UC, upper canine; MD mesiodistal; Eq, equation; CI, confidence interval.

Table 6 Comparison between the real values of the MD dimensions of lower canine and the predicted values according to the different regression equations developed.

Equation	N	Diff.	*t*	*Sig.*
Eq. (1)	17	−0.066	−0.667	0.515
Eq. (2)	10	−0.163	−1.086	0.306
Eq. (3)	19	−0.094	−0.873	0.394
Eq. (4)	17	−0.082	−0.828	0.420

N, number of individuals; Diff., mean value of the differences; t, Student's t-test; Sig., significance; Eq, equation.

Table 7 Comparison between the real values of the MD dimensions of lower canine and the predicted values according to the different regression equations developed.

Equation	N	Diff.	ICC	Agreement value
Eq. (1)	17	−0.066	0.571	Moderate
Eq. (2)	10	−0.163	0.516	Moderate
Eq. (3)	19	−0.094	0.485	Moderate
Eq. (4)	17	−0.082	0.585	Moderate

N, number of individuals; Diff., mean value of the differences; ICC, intraclass correlation coefficient.

not considered anthropologically. That is why the studies that offer the prediction of the size of the teeth individually are those that have relevance for dental anthropology.

The results of this work contrast with those obtained by Viciano and Tanga[12] for an archaeological population; their results showed that the size of the permanent canines can be estimated with high precision using the dimensions of the posterior teeth (premolars and molars), so that the predicted values for the canines can be applied with great reliability for estimation of the sex of bone remains by means of the specific functions developed. The values of this study show high correlation and determination coefficients ($r = 0.709–0.889$; $r^2 = 0.502–0.791$, respectively). There is a similarity with our study in that, at the coronary level, it is the MD diameters of the lower canine that show the highest correlation values. The study developed by Moorrees & Reed[31] for analysis of the correlation between MD diameters of different teeth shows a weak correlation with the dimensions of the canine, either higher ($r = 0.21–0.49$) or lower ($r = 0.40–0.53$). Although these results are inferior to those found in the present study, they are consistent with the highest degree of correlation found in the lower canine with respect to the superior. On the other hand, Lima et al.[29] obtained a strong correlation between the sizes of the lower canine and those of the first lower premolar ($r = 0.82$) and a weaker correlation with respect to the second lower premolar ($r = 0.62$).

Numerous studies indicate the need to analyse the results of different types of dental study already published, due to population variations.[9,32–34] Although they do it in the dental context, studies such as that of Lara et al.[26] have analysed the correlation between dental sizes in the Chilean population, finding correlation values ($r = 0.635–0.690$) similar to those of the present study.

The excellent degree of agreement found for the concordance and repeatability of the observations shows their validity in the ICC results. Not only are the dimensions obtained by a single observer reliable, but they are also replicable by the second. This validity obtained between observations is consistent with the results obtained in other dental studies, either by taking measurements with dental calliper[9,10,21] or by applying traditional measures in 3D digital dentition models.[35–38]

There is a moderate correlation between the dimensions of the permanent canines and those of the premolars and molars, the correspondence between real and predicted canine dimensions being equally moderate. However, the absence of a strong correlation prevents application of the predicted values for canines for subsequent predictions, such as in the estimation of sex.

There is no consensus on the number of observations needed for developing linear regression equations; however, Knofczynski and Mundfrom[39] propose a minimum of 35 observations to develop linear regression equations with two predictor variables, and 45 observations to develop regression equations with three predictor variables. These proposed numbers are for a good prediction level when the r^2 value is near 0.5. Our results are soothing because for Equations Eq (1), Eq (2) and Eq (3) (with two variable predictors), the number of observations to construct the diverse equations were 49, 41 and 53, respectively. For Eq (4) (three variable predictors) 48 observations were used.

Conflicts of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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