

Alternative Dental Measurements: Correlation Between Cervical and Crown Dimensions

J. Viciano¹, I. Alemán¹, R. D'Anastasio², L. Capasso²

¹ Department of Legal Medicine, Toxicology and Physical Anthropology, Medicine Faculty, University of Granada, Avenida de Madrid 11, Granada 18012, Spain. E-mail: joanviba@ugr.es

² Department of Human Movement Sciences, Section of Anthropology, State University "G. D'Annunzio", Chieti, Italy

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Introduction

Odontometrics are important in dental anthropology in a variety of applications: for the study of sexual dimorphism (Ditch and Rose, 1972; Viciano et al., 2011), trends in dental reduction of Late Pleistocene and Early Holocene humans (Brace et al., 1987; Calcagno and Gibson, 1991), and directional or fluctuating asymmetry in past human populations (Kieser and Groeneveld, 1988; Townsend, 1981), among others.

Teeth are routinely measured by mesiodistal and buccolingual crown diameters; however, due to dental attrition is the most significant cause of missing data in odontometric research, is necessary to use alternative dimensions to mitigate this problem, particularly measurements at the cervix of the tooth and measurements along the diagonal axis in molars (Hillson et al., 2005; Stojanowski, 2007).

The aims of this study are (i) quantify sample size benefits of cervical dimensions and identify those teeth most likely to benefit from substitution, (ii) compare bilateral asymmetry to determine if the magnitude of asymmetry differed between crown and cervical dimensions; this also speaks to the appropriateness of antimer substitution and, (iii) determine whether cervical dimensions demonstrate more or less variability than crown dimensions.

Materials and Methods

This study was conducted on the skeletal remains of 90 victims (53 males, 36 females, 1 individual of uncertain sex; aged between 20 and 60 years) who died while trying to flee by sea on the ancient beach of Herculaneum (Naples, Italy), during the eruption of the volcano Vesuvius on 24th/25th August, 79 AD. These individuals are housed in the Museum of Biomedical Sciences of Chieti, Italy. All of them either preserve fully erupted teeth or at least completely formed tooth crowns.

Dental measurements of each tooth were collected at the level of maximum and diagonal diameters of the crown and cervix, following the conventions of Hillson et al. (2005).

All measurements were taken using a digital dental caliper with an accuracy of 0.01 mm. Four dimensions were collected for incisors, canines and premolars and eight dimensions for molars.

All statistical analyses were performed using the SPSS 15.0 software program. Bilateral asymmetry between left and right antimeres in the same individual was calculated following Harris and Nweeia (1980) where

$$d = |L - R| / (L + R / 2)$$

with L = left, R = right. Paired t -tests and Pearson

product-moment correlations were used to compare the corresponding teeth on each side of the arch.

The relationships between different measurements were investigated through Pearson product-moment correlations. In addition to consideration of cervical measurements versus their equivalent maximum crown diameters, diagonal diameters were compared with the maximum mesiodistal and buccolingual diameters. The *robustness index* - a dental index explored in dental anthropology research - gives an approximate occlusal crown area and is the product of mesiodistal and buccolingual crown diameters. In the present study, maximum crown diameters were multiplied together to produce a "maximum crown area", cervical diameters were similarly multiplied to produce a "cervical crown area", and diagonals were similarly multiplied to produce a "diagonal crown area".

Results

Tab. 1 shows data on the representation of mesiodistal, buccolingual and diagonal diameters. The values represent the number of teeth for which only crown or cervical dimensions were recorded, the difference in representation between these dimensions, and the combined (left and right) increase in sample size and percent improvement (or not) that offers the use of cervical dimensions. Although the sample sizes compared to the theoretical maximum ($N = 180$) were low for all measurements, cervical dimensions were better represented for maxillary and mandibular anterior teeth and on both sides, compared with posterior teeth.

The largest percentual increase was observed in the upper and lower incisors and canines for mesiodistal and buccolingual diameters, and in the first molar for the diagonal diameters.

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	Left			Right			Combined	Percentage
	Crown	Cervix	Diff	Crown	Cervix	Diff		
Mesiodistal								
I ¹	12	35	+23	7	41	+34	+57	31.67%
I ²	10	29	+19	11	25	+14	+33	18.33%
C'	17	35	+18	21	32	+11	+29	16.11%
PM ¹	27	32	+15	27	30	+3	+18	10.00%
PM ²	23	32	+9	18	34	+16	+25	13.89%
M ¹	21	14	-7	21	20	-1	-8	-4.44%
M ²	36	11	-25	36	24	-12	-37	-20.56%
M ³	32	10	-22	35	16	-19	-41	-22.78%
I ₁	4	19	+15	6	23	+17	+32	17.78%
I ₂	14	26	+12	15	21	+6	+18	10.00%
C ₁	11	24	+13	7	23	+16	+29	16.11%
PM ₁	33	44	+11	34	41	+7	+18	10.00%
PM ₂	17	26	+9	21	35	+14	+23	12.78%
M ₁	32	31	-1	32	27	-5	-6	-3.33%
M ₂	35	31	-4	44	12	-32	-36	-20.00%
M ₃	29	6	-23	26	4	-22	-45	-25.00%
Buccolingual								
I ¹	20	39	+19	17	37	+20	+39	21.67%
I ²	17	27	+10	20	27	+7	+17	9.44%
C'	24	49	+25	30	46	+16	+41	22.78%
PM ¹	44	37	-7	48	37	-11	-18	-10.00%
PM ²	45	43	-2	46	50	-4	-6	-3.33%
M ¹	27	25	-2	33	26	-7	-9	-5.00%
M ²	36	26	-10	37	31	-6	-16	-8.89%
M ³	31	14	-17	35	17	-18	-35	-19.44%
I ₁	5	11	+6	8	13	+5	+11	6.11%
I ₂	12	22	+10	13	24	+11	+21	11.67%
C ₁	6	28	+22	7	36	+29	+51	28.33%
PM ₁	48	54	+6	56	53	-3	+3	1.67%
PM ₂	46	45	-1	51	47	-4	-5	-2.78%
M ₁	29	33	+4	36	30	-6	-2	-1.11%
M ₂	42	30	-12	53	32	-21	-33	-18.33%
M ₃	37	11	-26	42	16	-26	-52	-28.89%
Diagonal								
MBDLM ¹	23	26	+6	25	28	+3	+9	5.00%
MBDLM ²	36	29	-7	36	35	-1	-8	-4.44%
MBDLM ³	32	16	-16	32	24	-8	-24	-13.33%

	Left			Right			Combined	Percentage
	Crown	Cervix	Diff	Crown	Cervix	Diff		
MLDBM ¹	23	28	+5	27	25	-2	+3	1.67%
MLDBM ²	39	30	-9	40	33	-13	-22	-12.22%
MLDBM ³	30	15	-15	32	24	-8	-23	-12.78%
MBDLM ₁	30	33	+3	31	31	0	+3	1.67%
MBDLM ₂	42	31	-11	49	33	-16	-27	-15.00%
MBDLM ₃	32	15	-17	35	19	-16	-33	-18.33%
MLDBM ₁	29	33	+4	29	33	+4	+8	4.44%
MLDBM ₂	39	23	-16	46	20	-26	-42	-23.33%
MLDBM ₃	30	7	-23	31	10	-21	-44	-24.44%

Diff = difference between crown and cervical sample sizes

Tab. 1. Sample sizes for crown and cervical dimensions

Tab. 2 shows data of bilateral asymmetry. The results generally show that the total difference between right and left sides in the crown is higher than at cervical level (1.115 vs. 0.921), and is higher in mandibular teeth than maxillary teeth (1.147 vs. 0.889). In particular, canine is the

tooth less asymmetric in all crown and cervical dimensions analyzed. Although asymmetries statistically significant are found in some dimensions, antimeric pairs have a high correlation coefficients statistically significant.

	Crown					Cervical				
	N	d	t	r		N	d	t	r	
Mesiodistal										
I ¹	5	0.021	0.377	0.930	*	25	0.013	-1.014	0.976	***
I ²	6	0.016	-0.430	0.997	***	14	0.028	0.358	0.921	***
C'	9	0.011	0.254	0.943	***	16	0.016	-0.218	0.974	***
PM ¹	14	0.018	-2.257	0.941	*	18	0.019	0.000	0.952	***
PM ²	7	0.017	-0.558	0.831	*	14	0.020	0.633	0.921	***
M ¹	12	0.016	1.840	0.961	***	9	0.032	2.316	0.938	***
M ²	27	0.018	0.728	0.930	***	4	0.027	-2.449	0.952	*
M ³	21	0.043	-1.231	0.784	***	5	0.042	-1.166	0.610	
I ₁	3	0.017	5.965	0.998	*	13	0.022	-0.550	0.858	***
I ₂	9	0.009	1.483	0.983	***	12	0.010	0.592	0.982	***
C ₁	3	0.000	0.000	1.000	**	9	0.026	-1.118	0.956	***
PM ₁	13	0.022	0.138	0.865	***	26	0.019	-0.329	0.935	***
PM ₂	4	0.025	-1.687	0.874		13	0.018	-0.246	0.922	***
M ₁	19	0.017	-3.405	0.926	**	14	0.016	-1.014	0.934	***
M ₂	23	0.027	-1.517	0.750	***	9	0.021	-0.904	0.928	***
M ₃	15	0.030	-0.983	0.776	***	2	0.027	1.000	-1.000	***
Buccolingual										
	12	0.008	1.143	0.972	***	26	0.011	0.596	0.951	***

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	Crown						Cervical					
	N	d	t		r		N	d	t		r	
	9	0.020	1.513		0.959	***	13	0.021	-0.398		0.862	***
	21	0.010	-1.349		0.986	***	32	0.011	1.210		0.972	***
	35	0.016	0.275		0.940	***	20	0.024	-0.028		0.925	***
	32	0.014	1.028		0.954	***	31	0.020	-1.161		0.940	***
	21	0.008	2.599	*	0.984	***	14	0.008	-1.571		0.987	***
	27	0.022	-1.524		0.809	***	15	0.020	-1.266		0.933	***
	19	0.037	-0.214		0.796	***	7	0.053	0.840		-0.320	
	1	0.005	--	--	--	--	7	0.011	0.375		0.985	***
	9	0.014	0.707		0.965	***	13	0.026	-0.552		0.548	
	5	0.015	-0.466		0.980	**	18	0.012	0.904		0.967	***
	38	0.013	0.383		0.938	***	41	0.014	0.571		0.960	***
	32	0.023	-2.607	*	0.891	***	35	0.015	-0.316		0.958	***
	20	0.008	-0.904		0.964	***	16	0.012	1.773		0.963	***
	31	0.015	0.165		0.921	***	24	0.015	0.089		0.937	***
	27	0.024	-1.653		0.857	***	5	0.038	-2.164		0.904	*
Diagonal												
	14	0.013	1.737		0.908	***	16	0.007	1.342		0.980	***
	27	0.020	-1.589		0.911	***	19	0.021	-0.041		0.920	***
	20	0.037	-0.028		0.908	***	10	0.047	0.447		0.692	*
	18	0.120	1.859		0.972	***	18	0.016	-0.730		0.969	***
	29	0.102	0.172		0.919	***	18	0.020	-2.231	*	0.944	***
	19	0.130	0.287		0.839	***	9	0.050	-0.164		0.698	*
	18	0.009	-0.222		0.933	***	15	0.013	-1.581		0.983	***
	32	0.014	0.021		0.933	***	23	0.015	0.663		0.842	***
	22	0.019	0.203		0.895	***	9	0.014	0.172		0.908	***
	17	0.035	-1.513		0.911	***	17	0.010	1.047		0.949	***
	25	0.029	0.690		0.940	***	14	0.022	0.940		0.950	***
	17	0.032	1.201		0.818	***	2	0.019	0.481		-1.000	--
N = number of pairs of antimere teeth; d = mean of (absolute value of left-right size difference divided by mean value of right and left size); t = paired Student's t-test and r = Pearson product-moment correlation statistically significant at *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001												

Tab. 2. Bilateral asymmetry of crown and cervical dimensions

Tab. 3 shows that the maximum diameters of the crown and the equivalent cervical diameters generally do not show a strong correlation (rather moderate), although all correlations are positive. The higher correlations are observed in both mesiodistal and buccolingual diameters for upper lateral incisors and upper and lower canines, and in buccolingual diameter of upper and lower premolars. The molar correlations are not high.

Similarly, most of the correlations between mesiodistal and buccolingual diameters are low for both crown and cervical definitions.

For diagonal diameters of molars, Tab. 4 shows that there are relatively high correlations between the diagonal diameter of the crown and the diagonal diameter at cervical level, with the exception of the first lower molar, that shows a lower correlation. In addition, the

mesiobuccal-distolingual diagonal is also moderately correlated with the mesiolingual-distobuccal diagonal for both crown and cervical dimensions. The maximum diagonal diameters are also moderately correlated with

the maximum crown diameters (Tab. 5), and the cervical diagonal diameters are highly correlated with the cervical diameters (Tab. 6), with the exception of the upper third molar.

	Crown diameter vs. cervical diameter						Mesiodistal diameter vs. buccolingual diameter					
	Mesiodistal			Buccolingual			Crown			Cervical		
	N	r		N	r		N	r		N	r	
I ¹	12	0.770	**	26	0.660	***	15	0.578	*	61	0.583	***
I ²	14	0.876	***	21	0.849	***	15	0.722	**	37	0.550	***
C'	20	0.818	***	41	0.950	***	32	0.589	***	50	0.820	***
PM ¹	31	0.618	***	54	0.876	***	47	0.747	***	47	0.658	***
PM ²	24	0.613	**	66	0.909	***	34	0.722	***	53	0.709	***
M ¹	19	0.755	***	35	0.840	***	36	0.847	***	23	0.850	***
M ²	25	0.697	***	44	0.643	***	57	0.562	***	28	0.573	**
M ³	19	0.010		23	0.397		58	0.499	***	16	0.458	
I ₁	4	0.741		7	0.845	*	5	0.370		19	0.492	*
I ₂	12	0.692	*	18	0.478	*	10	0.322		31	0.350	
C ₁	6	0.882	*	9	0.917	***	3	0.992		31	0.690	***
PM ₁	37	0.656	***	80	0.860	***	54	0.657	***	75	0.683	***
PM ₂	22	0.530	*	65	0.857	***	30	0.701	***	46	0.702	***
M ₁	34	0.752	***	39	0.714	***	49	0.442	**	37	0.736	***
M ₂	26	0.698	***	43	0.874	***	64	0.525	***	29	0.831	***
M ₃	9	0.598		20	0.887	***	44	0.589	***	9	0.523	

N = number of teeth; r = Pearson product-moment correlation statistically significant at *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001

Tab. 3. Correlations between crown and cervical diameters

	Crown diameter vs. cervical diameter						MBDL diameter vs. MLDB diameter					
	MBDL			MLDB			Crown			Cervical		
	N	r		N	r		N	r		N	r	
M ¹	31	0.751	***	31	0.735	***	42	0.772	***	48	0.836	***
M ²	46	0.896	***	47	0.796	***	69	0.764	***	56	0.724	***
M ³	26	0.891	***	23	0.834	***	59	0.755	***	37	0.785	***
M ₁	35	0.650	***	38	0.652	***	52	0.781	***	61	0.888	***
M ₂	44	0.841	***	26	0.762	***	80	0.860	***	39	0.676	***
M ₃	23	0.804	***	11	0.766	*	53	0.834	***	16	0.802	***

N = number of teeth; MBDL = mesiobuccal-distolingual diagonal diameter; MLDB = mesiolingual-distobuccal diagonal diameter
r = Pearson product-moment correlation statistically significant at *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001

Tab. 4. Correlations between crown and cervical mesiobuccal-distolingual diameters and mesiolingual-distobuccal diagonal diameters.

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	MLDB crown diameter						MLDB crown diameter					
	vs. maximum buccolingual crown diameter			vs. maximum buccolingual crown diameter			vs. maximum mesiodistal crown diameter			vs. maximum mesiodistal crown diameter		
	N	r		N	r		N	r		N	r	
M ¹	34	0.810	***	48	0.803	***	30	0.732	***	49	0.897	***
M ²	58	0.713	***	63	0.817	***	63	0.730	***	67	0.755	***
M ³	54	0.487	***	57	0.931	***	56	0.474	***	57	0.745	***
M ₁	49	0.686	***	55	0.838	***	46	0.666	***	55	0.785	***
M ₂	63	0.720	***	86	0.840	***	56	0.761	***	82	0.852	***
M ₃	41	0.856	***	63	0.853	***	37	0.871	***	59	0.781	***

N = number of teeth; MBDL = mesiobuccal-distolingual diagonal diameter; MLDB = mesiolingual-distobuccal diagonal diameter
r = Pearson product-moment correlation statistically significant at *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001

Tab. 5. Correlations between diagonal and maximum crown diameters.

	MBDL cervical diameter						MLDB cervical diameter					
	vs. Mesiodistal cervical			vs. Buccolingual cervical			vs. Mesiodistal cervical			vs. Buccolingual cervical		
	N	r		N	r		N	r		N	r	
M ¹	25	0.845	***	49	0.873	***	28	0.880	***	46	0.921	***
M ²	27	0.494	**	49	0.828	***	28	0.630	***	47	0.770	***
M ³	19	0.129		26	0.460	*	16	0.371		24	0.461	*
M ₁	42	0.832	***	57	0.900	***	41	0.889	***	58	0.867	***
M ₂	31	0.880	***	56	0.780	***	26	0.770	***	40	0.894	***
M ₃	9	0.678	*	26	0.733	***	9	0.834	**	15	0.726	**

N = number of teeth; MBDL = mesiobuccal-distolingual diagonal diameter; MLDB = mesiolingual-distobuccal diagonal diameter
r = Pearson product-moment correlation statistically significant at *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001

Tab. 6. Correlations between cervical diagonals and cervical diameters.

In addition, when diameters are multiplied to produce crown areas (robustness index), the maximum crown area shows

high correlations with the cervical area, and both of them show high correlations with the diagonal crown area (Tab.7).

	Crown area vs. cervical area			Diagonal crown area vs. crown area			Diagonal cervical area vs. cervical area		
	N	r		N	r		N	r	
I ¹	8	0.854	***						
I ²	8	0.969	***						
C'	16	0.907	***						
PM ¹	24	0.858	***						
PM ²	19	0.778	***						
M ¹	13	0.811	***	30	0.886	***	23	0.972	***
M ²	19	0.797	***	51	0.888	***	22	0.909	***
M ³	11	0.235		49	0.879	***	12	0.451	
I ₁	2	-1.000	—						

	Crown area vs. cervical area			Diagonal crown area vs. crown area			Diagonal cervical area vs. cervical area		
	N	r		N	r		N	r	
I ₂	6	0.884	*						
C ₁	1	—	—						
PM ₁	29	0.871	***						
PM ₂	18	0.669	**						
M ₁	20	0.809	***	43	0.917	***	34	0.972	***
M ₂	16	0.781	***	54	0.896	***	22	0.898	***
M ₃	7	0.687		32	0.968	***	9	0.933	***

N = number of teeth; r = Pearson product-moment correlation statistically significant at *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001
 Robutness index is calculated as:
 Crown area = MD_{crown} × BL_{crown};
 Cervical area = MD_{cervical} × BL_{cervical}
 Diagonal crown area = MBDL_{crown} × MLDB_{crown}
 Diagonal cervical area = MBDL_{cervical} × MLDB_{cervical}

Tab. 7. Relationships between different forms of crown area (robutness index).

Discussion

The results of comparative analysis of crown and cervical dimensions have produced mixed results. These data reflect the fact that cervical measurements are subject to multiple causes of missing data. For example, in the population of Herculaneum we have observed: excessive occlusal wear, cervical caries, cervical calculus and presence of carbonized material attached on the surface.

This study reveals that (i) the teeth that most benefit from cervical dimensions, for which the measurements are more useful in odontometrics and anthropological research, are the anterior teeth, both maxillary and mandibular, compared with posterior teeth, (ii) there is no inconvenience in the antimer substitution. Asymmetries statistically significant in the measurements of some teeth were found; however, high correlation coefficients statistically significant between antimeric pairs were obtained, and (iii) the results suggest, in general, that the cervical diameters and their homologous crown diameters reflect similar tooth characteristics and can be adequately used in odontometric analysis, despite of the limited sample-size of Herculaneum.

References

- Brace C.L., Rosenberg K.R., Hunt K.D. 1987. Gradual change in human tooth size in the late Pleistocene and post-Pleistocene. *Evolution*, 41: 705-720.
- Calcagno J.M., Gibson K.R. 1991. Selective compromise: evolutionary trends and mechanisms in hominid tooth size. In: Kelley M.A., Larsen C.S., editors. *Advances in dental anthropology*. Wiley-Liss, New York: 59-76.
- Ditch L.E., Rose J.C. 1972. A multivariate dental sexing technique. *Am. J. Phys. Anthropol.*, 37: 61-64.
- Harris E.F., Nweeia M.T. 1980. Dental asymmetry as a measure of environmental stress in the Ticuna Indians of Colombia. *Am. J. Phys. Anthropol.*, 53: 133-142.
- Hillson S., FitzGerald C., Flinn H. 2005. Alternative dental measurements: proposals and relationships with other measurements. *Am. J. Phys. Anthropol.*, 126: 413-426.
- Kieser J.A., Groeneveld H.T. 1988. Fluctuating odontometric asymmetry in an urban South African Black population. *J. Dent. Res.*, 67: 1200-1205.
- Stojanowski C.M. 2007. Comment on "Alternative dental measurements" by Hillson et al. *Am. J. Phys. Anthropol.*, 132: 234-237.
- Townsend G.C. 1981. Fluctuating asymmetry in the deciduous dentition of Australian aboriginals. *J. Dent. Res.*, 60: 1849-1857.
- Viciano J., Alemán I., D'Anastasio R., Capasso L., Botella M.C. 2011. Odontometric sex discrimination in the Herculaneum sample (79 AD, Naples, Italy), with application to juveniles. *Am. J. Phys. Anthropol.*, 145: 97-106.