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Occlusal Polygon Area of the Molars in Six Colombian Ethnic Groups

Área del Polígono Oclusal de Molares en Seis Grupos Étnicos de Colombia

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SUMMARY: Descriptive observational cross-sectional study to determine the AOP of the second molars (55, 65, 75, 85) and the first permanent molars (16, 26, 36 and 46) in 459 study models corresponding to six ethnic groups in Colombia, Embera indigenous of Alto Baudó (Chocó), Caucasoid mestizos of Cali (Valle del Cauca), African descent of Cali (Valle del Cauca), Misak indigenous of Silvia (Cauca), Nasa indigenous of Morales (Cauca), and indigenous of Leticia (Amazonas). There were no significant differences of AOP among the six ethnic groups except when compared to the Amazon Indians with African descent of Cali, Embera indigenous and Nasa indigenous. There was no sexual dimorphism except tooth 65 for all ethnic groups. There was bilateral symmetry except between teeth 16 and 26. The distance matrix showed that Caucasoid mestizos of Cali were grouped with microdont populations, Amazon indigenous, Embera indigenous, Misak indigenous and Nasa indigenous, and African descendants of Cali were grouped with mesodont populations.The Embera and Amazon indigenous had the highest values of OAP associated with the relative isolation and less mestizaje. Overall, there was no sexual dimorphism or bilateral asymmetry. This study coincides with the different theories about reducing the size of the teeth as evolutionary characteristic of hominids.

KEY WORDS: Dental anthropology; Dental dimensions; Occlusal surface; Intercuspal distance; Occlusal polygon area.

INTRODUCTION

Dental anthropology is related to the observation, recording, analysis and understanding of all information that can be obtained from the developmental, pathological, cultural and therapeutic variations of teeth. Hence, taking into consideration the conditions of life, culture, food and processes adaptation of present and past human populations, with regard to dental morphology, dental dimensions, oral diseases, and teeth modifications (Rodríguez, 2003; Scott & Turner II, 1997). In this study, analysis of dental dimensions or odontometry consists of obtaining and recording different measurements of the crowns and roots of teeth, useful in the clinical field for predicting space during maxillary orthopedics and orthodontics treatments; in the anthropological field to establish phylogenetic relationships among species of hominids disappeared and different human populations, and in forensic field to estimate the sex of individuals in the identification processes (Scott & Turner II).

The most studied odontometric measures are the mesio-distal and vestibule-palatal diameters (lingual in the lower teeth case) since these dimensions are rarely affected by wear caused by attrition during mastication, the abrasive properties of some food and habits; and pathological conditions such as bruxism (Moorrees *et al*., 1957; Mayhall, 2000). However, in the anthropological context, the occlusal polygon area (OPA) has taken a great interest in the study of occlusal surfaces related with dental size in hominids. This measure arises from straight lines interconnected the cusp apexes of the main cusps, forming an irregular four-sided polygon, in the case of primary and permanent maxillary molars, and five sides in the case of primary and permanent mandibular molars (Morris, 1986; Bailey *et al*., 2008).

Through the OPA the behavior of the distance between the main cusps of molars can be explained, and

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how they relate to their antagonist. Thus contributing to the analysis of sexual dimorphism, bilateral symmetry, correspondence and the biological relationship between hominids and past and present human populations, in order to clarify the historical, cultural and biological (macro and micro-evolutive) process. The above contributes to understanding the origin, formation, contacts, displacement, migration, paths and isolates that have as result the populating of the planet and ethnic humanity variation (Bailey, 2004). Therefore, the aim of this study was to determine the OPA of the second primary molars (um2, lm2) and first permanent molars (UM1, LM1) in six Colombian ethnic groups.

MATERIAL AND METHOD

Type of study and sample. Descriptive observational cross-sectional study to determine the OPA of the second primary molars and the first permanent molars in 459 study models corresponding to individuals of both sexes, ages between six and eighteen, and from six Colombian ethnic groups. Study models used in this study were obtained from previous studies conducted by dental anthropology and Forensic Dentistry Research Branch at the School of Dentistry at the University of Valle. Thus a sample was constituted with 18 Embera indigenous from Alto Baudo (Choco) –12 women and 6 men– (Moreno *et al*., 2016), 25 Caucasoid mestizos from Cali (Valle del Cauca) –13 women and 12 men– (Aguirre *et al*., 2006), 156 African descents from Cali (Valle del Cauca) –79 women and 77 men– (García *et al*., 2015), 60 Misak indigenous from Silvia (Cauca) –34 women and 26 men– (García *et al*.). 100 Nasa indigenous from Morales (Cauca) –62 women and 38 men– (Díaz *et al*., 2014), and 100 indigenous from Leticia (Amazonas) –56 women and 44 men– (Aragón *et al*., 2008). The models were taken into account whose second primary molars and first permanent molars present without wear or fracture (Fig. 1).

Fig. 1. Map of Colombia with geographical location of ethnic groups considered in this study. 1. Embera indigenous of Baudó (Chocó); 2. Caucasoid Mestizos and Afro-descendants from Cali (Valle del Cauca); 3. Misak indigenous of Silvia (Cauca); 4. Nasa indigenous of Morales (Cauca); and 5. Amazon indigenous of Leticia (Amazonas).

Ethical considerations. The study models were obtained from previous research supported by the Institutional Ethics Human Committee of the Universidad del Valle (Colombia), so that the sample was formed from the settlements and informed consent, which stated that study models could be used in future studies developed in dental anthropology and by the forensic dentistry research group at the School of Dentistry at the Universidad del Valle.

Observation. The study models included were determined the OPA of the second primary molars and the first permanent molars through ImageJ® software. The study models were placed in a paralellometer and photographed with a Nikon D3100® digital camera 2X to a focal length of six centimeters and a witness metric millimeters. Once transferred the image to ImageJ® software, the "irregular polygon" tool was used marking the vertices of the main cusps of the teeth. For primary and permanent maxillary molars four distances were determined between mesiobuccal, mesiolingual, distolingual and distobuccal cusps, and primary and permanent lower molars five distances were determined between mesiobuccal, mesiolingual, distolingual and distobuccal cusps (Fig. 2). Finally, the command "measure" was executed to get the OPA from the intercuspids distances, initially in pixels and then by a conversion scale expressed in millimeters. Prior to the measurement, two observers learned to manually locate the cusp vertex and set the distance intercuspal under standardization protocol and

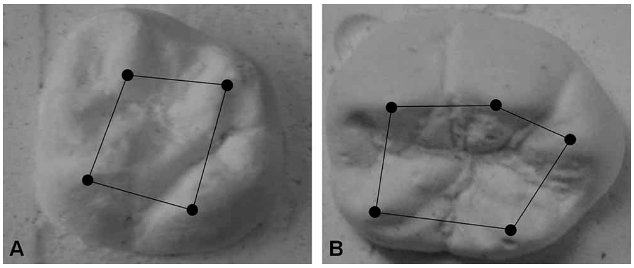

Fig. 2. Occlusal polygon area in the upper first molar and lower first molar.

double-blind to control bias and achieve the unification of the observation criteria. Through a stereomicroscope (10x) and a digital caliper type Vernier (Ubermann® model 47257 with margin of error of 0.02 mm) was placed at each vertex cusp and the respective distance was determined. The estimated of the degree of concordance was performed by the coefficient of correlation and agreement in the Software Stata 6.0, the results for the criteria of interobserver (observer vs. advisor) were 94 % and 91 %, and intraobserver (observer vs. observer) were 96 % and 90 % respectively.

Statistical analysis. The data obtained from the OPA were entered into an Excel template and processed in the Software Stata® 13. An exploratory analysis was carried out to determine the distribution of the quantitative variable (occlusal polygon area) and bivariate analysis to determine the frequency of categorical variables. Shapiro-Wilks test was used to evaluate the normality of the distribution of OPA for sexual dimorphism (T-Student test was applied for normal values and The Mann-Whitney Rank Sum Test for non-standard values) and Wilcoxon test was used to evaluate bilaterality. To compare ethnic groups, ANOVA test was used for the values that had a normal distribution and Kruskal Wallis for those with non normal distribution. Subsequently, a Bonferroni post-ANOVA test was carried out to identify difference among groups. A $p<0.05$ was considered statistically significant. To determine the biological distances hierarchical cluster classification was used, by the Euclidean distance squared in IBM SPSS Statistics Software 21® and the dendrogram was obtained by the method of Ward.

RESULTS

The primary and permanent teeth for each sex throughout the study were 711 female and 533 male teeth, distributed by each ethnic group in 373 teeth of African descents from Cali, 290 teeth of Amazon indigenous, 150 teeth of Embera indigenous, 58 teeth of Caucasoid mestizos from Cali, 132 teeth of Misak indigenous and 261 teeth of Nasa indigenous. In the same way the distribution was obtained from OPA of temporary and permanent teeth in each ethnic group and in the whole sample. To evaluate the difference between women and men, the OPA´s average and the confidence interval of each tooth was obtained, and it was found that the tooth 65 presented sexual dimorphism –0,0349 value significance–. Likewise, the behavior of each tooth by sex can be observed. To evaluate the difference between the right side and the left side, the average OPA and the confidence interval was obtained of each tooth, and bilateral asymmetry was found between the teeth 16 and 26 –0,0286 value significance–. Finally, the six ethnic groups were pooled to compare OPA for each tooth. ANOVA test showed significant differences in the teeth 55 (0.0115), 65 (0.0036), and 75 (0.0052), and the Kruskal-Wallis test showed significant differences in the teeth 85 (0.0187), 26 (0.0001) and 46 (0.0965). Subsequently, the Bonferroni test was applied to identify differences between ethnic groups, considering only the first upper permanent molars since these biological affinities were estimated. Significant differences were found between Amazon indigenous with African descents from Cali (0.014), Embera (0.002) and Nasa indigenous (0.004) (Tables I-V; Figs. 3-5).

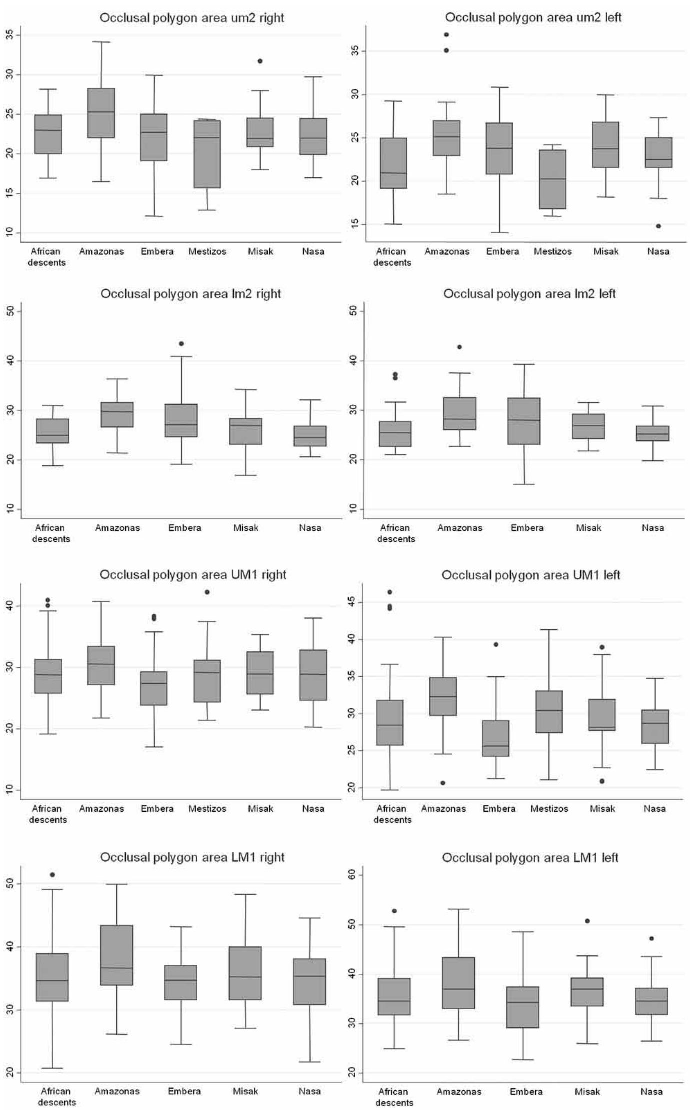

Fig. 3. Occlusal polygon area by tooth in each ethnic group.

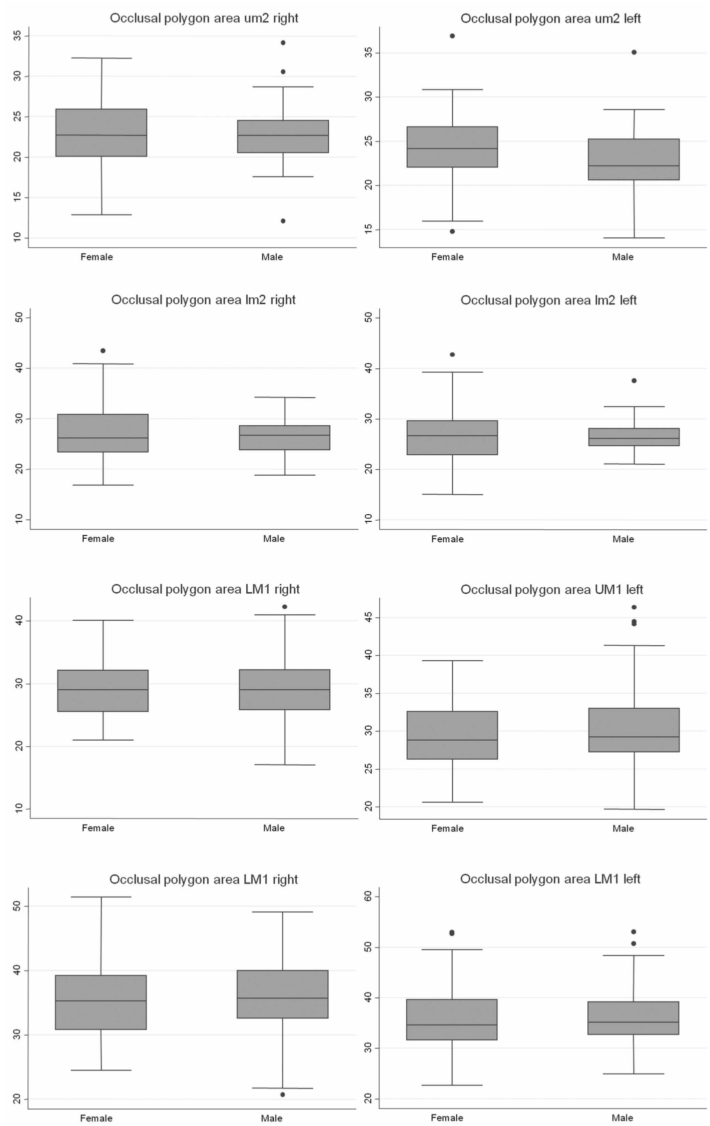

Fig. 4. Occlusal polygon area of each tooth on the entire sample.

The distance matrix and the dendrogram constructed to establish biological affinity between the six ethnic and other groups of hominids allowed to calculate macroevolutionary relationship to the study sample based on geographical and biological models of the distribution and behavior of averages OPA in the first upper permanent molars. This dendrogram showed that: Caucasoid mestizos from Cali formed a conglomerate first modern American and Asian populations, European and Asian Neanderthals and Neolithic groups; Amazon, Embera, Misak and Nasa indigenous people, and Afro-descendants from Cali formed a second cluster with modern Caucasoid; and the third cluster was formed by groups of Paleolithic, Homo erectus and contemporary European human groups (Morris; Bailey *et al*.; Fernandes *et al*., 2012; Martinón-Torres *et al*., 2013) (Fig. 6).

DISCUSSION

The results of this study regarding tooth size, sexual dimorphism, bilaterality and biological distances will be discussed considering that OPA corresponds to an alternative morphometric method scarcely studied. because most odontometric studies have focused on the study of mesiodistal and buccolingual diameters.20 However, different authors have demonstrated that the OPA is dependent on the size of the tooth crown (Sekikawa *et al*., 1986).

Dental size. Odontometry is the component of the dental anthropology that has contributed the most to the clarification of evolutionary processes of hominids; the distribution of human populations in the continental shelves of Africa, Europe and Asia; and the peopling of the Americas. Similarly, has contributed to the formation of world dental complexes (Moreno, 2013). Since the simplification of morphology and tooth size reduction have been the trend in the evolution of hominids, these have been grouped according to size of teeth as follows (Rodríguez): 1. The australopithecines were characterized by molarization of premolars and large size third molars, larger than the second

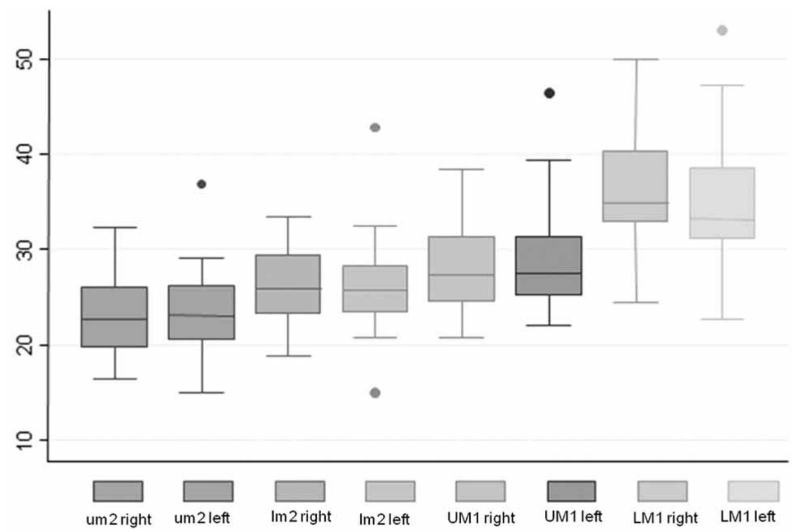

Fig. 5. Occlusal polygon area of each tooth by sex.

Table I. Distribution of molars by sex and ethnic group.

Ethnic group	Female			Male			Total
	n	%	N	n	%	N	
African descendants	195	28.57	195	178	27,57	178	373
Amazon Indigenous	172	31.07	367	118	30,9	296	290
Embera Indigenous	77	29.02	444	73	27,51	369	150
Caucasoid Mestizos	30	23.88	474	28	26,22	397	58
Misak Indigenous	78	28.51	552	54	29,42	451	132
Nasa Indigenous	159	27.35	711	102	28,2	553	261

n=Number of teeth; %=Average; N= Cumulative of number of teeth

Table II. Occlusal polygon area by ethnic group.

Tooth	African descendants		Amazon Indigenous		Embera Indigenous		Caucasoid Mestizos		Misak Indigenous		Nasa Indigenous	
	n	Average (IC 95%)	n	Average (IC 95%)	n	Average (IC 95%)	n	Average (IC 95%)	n	Average (IC 95%)	n	Average (IC 95%)
55	20	22.70 (21.15-24.25)	27	25.31 (23.56-27.07)	21	22.12 (20.27-23.98)	6	20.20 (15.00-25.39)	14	22.97 (20.90-25.05)	30	22.26 (21.10-23.43)
65	22	21.79 (20.21-23.36)	30	25.36 (23.90-26.83)	19	23.35 (21.28-25.43)	4	20.15 (13.79-26.51)	20	24.17 (22.65-25.68)	32	22.87 (21.87-23.88)
75	21	25.47 (23.86-27.07)	19	29.24 (27.25-31.23)	19	29.03 (25.77-32.28)	0	–	16	26.48 (23.91-29.04)	22	24.81 (23.42-26.20)
85	22	25.90 (23.88-27.91)	19	29.50 (26.98-32.01)	19	28.18 (25.27-31.10)	0	–	17	26.58 (25.09-28.07)	23	25.08 (23.98-26.18)
16t	70	28.68 (27.54-29.81)	47	30.84 (29.49-32.18)	17	27.53 (24.49-30.57)	23	28.96 (26.55-31.36)	15	29.09 (26.87-31.31)	37	28.47 (26.98-29.95)
26	71	29.29 (28.05-30.54)	47	32.11 (30.94-33.29)	16	26.99 (24.42-29.57)	25	30.43 (28.44-32.42)	16	29.41 (26.91-31.91)	38	28.45 (27.41-29.49)
36	75	35.34 (34.01-36.68)	45	38.16 (36.28-40.03)	18	34.34 (31.97-36.71)	0	–	15	36.19 (33.05-39.33)	39	34.86 (33.32-36.40)
46	72	35.71 (34.30-37.11)	46	38.01 (36.12-39.91)	21	34.61 (31.60-37.62)	0	–	19	36.38 (33.59-39.18)	40	34.78 (33.35-36.21)

Table III. Sexual dimorphism of occlusal polygon area.

Tooth	Female	Male	*p**
	Average (IC 95 %)	Average (IC 95 %)	
55	23.18 (22.15-24.20)	22.72 (21.69-23.75)	0,5389
65	24.08 (23.21-24.95)	22.67 (21.68-23.67)	0,0349
75	27.19 (25.75-28.63)	26.47 (25.34-27.61)	0,9467
85	27.14 (25.70-28.57)	26.67 (25.69-27.66)	0,8504
16	29.04 (28.18-29.90)	29.14 (28.10-30.18)	0,8754
26	29.40 (28.59-30.21)	30.12 (29.09-31.15)	0,3581
36	35.66 (34.57-36.74)	36.15 (34.90-37.39)	0,5567
46	36.05 (34.88-37.23)	35.94 (34.76-37.12)	0,7868

*p<0.05

Table IV. Bilateral symmetry of occlusal polygon area.

Tooth	n	Average of area (IC 95%)	*p*
55	118	22.99 (22.26-23.71)	0,41
65	127	23.46 (22.80-24.12)	01
75	97	26.92 (25.94-27.89)	0,65
85	100	26.94 (26.03-27.86)	64
16	209	29.09 (28.42-29.75)	0,02
26	213	29.73 (29.09-30.37)	86
36	192	35.88 (35.06-36.69)	0,36
46	198	36.00 (35.17-36.83)	96

*p<0.05

Table V. Comparison of OPA of maxillary/ mandibular first molars by ethnic group.

Ethnic group *	AC	AI	EI	CMC	MI	NI
AC	1.000	0.014	0.450	0.891	1.000	0.941
AI		1.000	0.002	0.666	0.316	0.004
EI			1.000	0.175	0.662	0.890
CMC				1.000	0.982	0.541
MI					1.000	0.981
NI						1.000

*AC=African descendants; AI= Amazon Indigenous; EI= Embera Indigenous; CMC= Caucasoid Mestizos; MI= Misak Indigenous; NI= Nasa Indigenous.

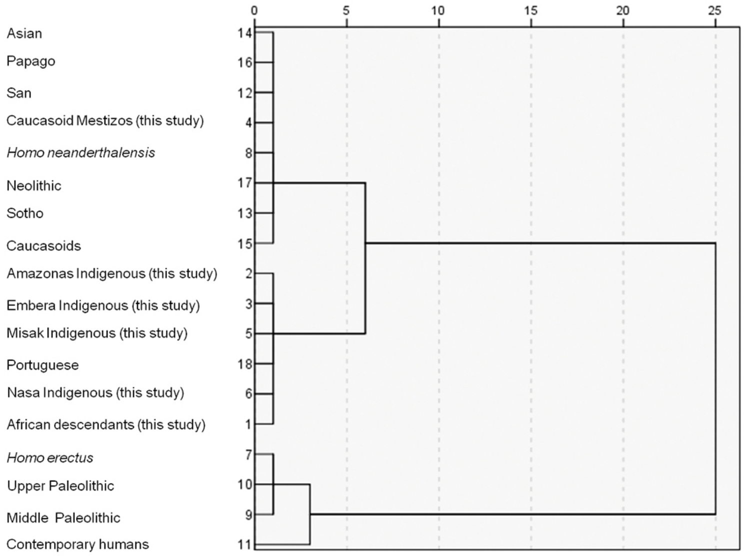

Fig. 6. Dendrogram derived from the distance matrix on the six ethnic groups in this study and other groups of hominids based on the average of the occlusal polygon area of the permanent maxillary first molars.

molars and these, in turn, larger than the first molars (M3>M2>M1); 2. Middle Pleistocene hominids, such as Homo erectus, are characterized by smaller size teeth than those of australopithecines, their ancestors, but larger than those of Homo sapiens and with the humanoid ratio of M1>M2>M3; 3. Homo neanderthalensis shows a reduction of molars; 4. Homo sapiens tend to reduce dental size with differential gradients in various regions of the world which starts an ethnic variation regarding the geographical distribution associated with the probable mutation effect theory involving cooked food and masticatory forces reduction; 5. The contemporary human populations support the simplification of the teeth explained through the theory of uncontrolled accumulation of mutations that have mismatched morphogenesis in aspects such as reduction of the rate of individual growth, reduction of tooth size, and the disappearance of sexual dimorphism associated with a variety of factors, including genetic isolation –which can increase the tooth size– and miscegenation or hybridization, –which, on the contrary, can generate reduction and simplification of structures–. Thus, the comparison of tooth size has allowed to group populations in four major population dental complexes (Australoids, Caucasoids, Mongoloids and Negroids); as follows: Australoids have the largest teeth (macrodont), there are no significant differences between Caucasoids (microdont) and Negroids; there are no differences between Mongoloids (mesodont) and Negroids, and there are considerable differences between Caucasoids and Mongoloids. In general terms, Negroids reflect minor differences compared to the other three complexes. In this sense, from among all ethnic groups taken into account in this study –the Caucasoid Mestizos of Cali (27.26 mm^2), the Nasa indigenous (28.36 mm^2), the Misak indigenous (28.57 mm^2) and African descendants of Cali (28.84 mm^2)–, groups with higher levels of miscegenation can be considered as mesodont with a tendency to microdontia, while the Embera indigenous (30.00 mm^2) and Amazon indigenous (31.00 mm^2) –groups more isolated– can be considered as mesodont with a tendency to macrodontia. Similarly, it was possible to determine that the Amazon indigenous people have a significantly higher OPA than other ethnic groups compared to groups Afro descendants of Cali, Nasa and Embera indigenous.

Miscegenation has become one of the factors that may have the greatest influence on the decrease of intercusp distances, and therefore, in the reduction of the OPA. The constant interaction of various genotypes during human evolution has caused a disparity in the morphometry of teeth related to differences in gene expression in odontogenesis (Jernvall & Jung, 2000). The protein-coding genes such as EDA, EDAR, HOXB2 or IGFBP1 have been involved in the tooth development and formation, number, and position of cusps (Kassai *et al*., 2005; Townsend *et al*., 2012). These multigene signals can be affected by the interaction between environment and genotype, –as is the case of the geographical distribution of ethnic groups and different levels of miscegenation– so that they can modify the distance between the enamel knots that will give rise to the cusps, which can increase or decrease the OPA to finally affect the size of the crown of the teeth (Hunter *et al*., 2010).

Sexual dimorphism. The study of tooth size has been used to understand the sexual dimorphism in the socioecological and phylogenetic evolution of primates including hominids. Sexual dimorphism is defined as an intraspecific difference between men and women that emerged during primate evolution associated with the size and evolutionary response to several factors, including territoriality, competition and distribution of resources. However, in modern human populations, the restriction of many of these factors has caused sexual dimorphism of the size of the teeth to have almost disappeared, except, perhaps, in the canine teeth (Schwartz *et al*., 2005). In this study there was no sexual dimorphism in the OPA among the six ethnic groups, except in the maxillary left first molar –significance value 0.0349–, which can be associated with low n of the group of Caucasoid Mestizos of Cali. This lack of sexual dimorphism coincides with the results of a study on tooth size in a population of mestizos in the same geographical region (Castillo *et al*., 2012).

Bilateral symmetry. One of the main features of the mammalian dentition is bilateral symmetry, that is, contralateral teeth of the same class and the same arch are morphometrically equal (Moreno). Although most studies in the context of dental anthropology take for granted bilateralism of morphological traits and dental metrics, this study sought to analyze bilateral symmetry of the OPA, finding that in the six ethnic groups there are several characteristics of bilateralism, except between the UM1, which was associated with the extreme minimum and maximum values of OPA of permanent maxillary right first molar (28.42 – 29.75) and the permanent maxillary left first molar (29.09 – 30.37), especially in the Caucasoid Mestizos from Cali.

Biological distances. To establish biological affinity of the sample of this study with global human populations, the distance matrix made possible to calculate the macroevolutionary biological relationships of the study sample; and the dendrogram made possible to establish a macroevolutionary model based on geographical and biological models of distribution and behavior of OPA on the permanent maxillary first molars in different ethnic groups. This way, three clusters were formed: Caucasoid Mestizos from Cali, European, and Asian populations related to Neanderthals and Neolithic groups, characterized by narrow occlusal molars and smaller OPA areas, were grouped together in the first cluster. While the other ethnic groups in this study and a group of modern Caucasoids, characterized by having a very similar OPA average, were grouped together in the second cluster; the group of Amazon indigenous was close to the first cluster, because of a greater OPA. And finally, Homo erectus, Upper and Middle Paleolithic groups, and contemporary Caucasoid populations, characterized by having the greatest OPA, were grouped together in the third cluster. Bailey *et al.* found that the narrower OPA of the permanent maxillary first molars were observed in Homo neanderthalensis, while the broader OPA were observed in the Upper Paleolithic Homo sapiens, so that H. neanderthalensis tended to narrow his OPA forming a rhomboidal polygon, while H. sapiens tended to broaden his OPA forming a quadrangular polygon very similar to australopithecine patterns (Gómez-Robles *et al*., 2007). Also, Martinón-Torres *et al*. found that the narrow OPA from compression on the cusp vertices into the mesiodistal development groove is a feature shared by the early Homo (heidelbergensis, neanderthalensis and predecessor) but absent in H. sapiens. That is why these groups –H. neanderthalensis and H. sapiens– are in the dendrogram of this study at the ends of the first and third cluster. Morris compared OPA of permanent maxillary molars in five ethnic groups finding relatively similar areas, slightly larger in Papago San and Sotho; however, smaller compared to other modern human groups. However, differences of OPA from the early Homo to modern humans have not been greater than two square millimeters (Bailey) in contrast to groups of indigenous people Australians, who have the largest teeth among all modern human populations (up to 30 % and 35 %); 32 while American populations show a trend for reduction, as was evidenced by OPA of paleoindians molars (Christensen, 1998).

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In conclusion, the averages of the occlusal polygon area of the maxillary and mandibular temporary and permanent molars have allowed classification of the six ethnic groups in clusters microdonts (caucasoid Mestizos from Cali) and mesodonts (Amazon, Embera, Misak and Nasa indigenous, and African descendants from Cali); however, Embera and Amazon indigenous were those who had the highest values associated with the relative isolation and less miscegenation. Overall, there was no sexual dimorphism or bilateral asymmetry. This study coincides with the different theories on the morphological simplification and reduction of tooth size as a characteristic of the evolution of hominids.

GARCIA, M.; GONZÁLEZ, N.; MARTÍNEZ, D.; TORRES, K.; MORENO, M.; JARAMILLO, A. & MORENO, F. Área del polígono occlusal de molares en seis grupos étnicos de Colombia. *Int. J. Morphol., 40(2)*:466-473, 2022.

RESUMEN: Estudio observacional descriptivo de corte transversal en el que se determinó el APO de los segundos molars deciduos (55, 65, 75, 85) y de los primeros molares permanentes (16, 26, 36, 46) en 459 modelos de estudio correspondientes a seis grupos étnicos de Colombia: Indígenas embera del Alto Baudó (Chocó), mestizos caucasoides de Cali (Valle del Cauca), afrodescendientes de Cali (Valle del Cauca), indígenas misak de Silvia (Cauca), indígenas nasa de Morales (Cauca) e indígenas de Leticia (Amazonas). No se encontraron diferencias significativas en el APO de los seis grupos étnicos, excepto entre indígenas del Amazonas y de afrodescendientes de Cali, e indígenas embera e indígenas nasa. No se evidenció dimorfismo exual en ninguno de los seis grupos. Hubo simetría bilateral, excepto entre los dientes 16 y 26. La matriz de distancias demostró que los mestizos caucasoides de Cali se agrupan con poblaciones microdontes, indígenas del amazonas, indígenas embera, indígenas misak e indígenas nasa; mientras que los afrodescendientes de Cali se agrupan con poblaciones mesodentes. Los indígenas embera y del Amazonas presentaron altos valores del APO, asociado a su aislamiento relativo y bajo mestizaje. En términos generales, no hubo dimorfismo sexual ni asimetría bilateral. Los resultados de este estudio concuerdan con diferentes teorías sobre la reducción del tamaño dental como una característica evolutiva de los himínidos.

PALABRAS CLAVE: Antropología dental; Dimensiones dentales; Superficie oclusal; distancia intercuspídea; Área del polígono oclusal.

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