

# We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

7,100

Open access books available

189,000

International authors and editors

205M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index  
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?  
Contact [book.department@intechopen.com](mailto:book.department@intechopen.com)

Numbers displayed above are based on latest data collected.  
For more information visit [www.intechopen.com](http://www.intechopen.com)



---

# Sexual Dimorphism in Human Teeth from Dental Morphology and Dimensions: A Dental Anthropology Viewpoint

---

Freddy Moreno-Gómez

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/55881>

---

## 1. Introduction

Based on the referenced literature and from a holistic and integrating viewpoint, dental anthropology is seen as an interdisciplinary field that integrates knowledge of anthropology, dentistry, biology, paleontology and paleopathology in order to study all the information provided by the human dentition, such as anatomical, developmental, pathological, cultural and therapeutic variations in consideration of the conditions of life, culture, food and adaptation processes of the past and present human populations, through morphology, size, disease and modifications of teeth [1,2].

Basically, dental anthropology is concerned with the study of morphological variation (dental morphological features) and metrics of the dentition of human populations over time (prehistoric and modern) and space (ethnic influences) and their relation with the processes of adaptation and dietary changes that led to the evolution of the dental system and the human race [3]. This is possible because the enamel is the hardest tissue of the human body and has a high capacity to preserve itself even in extreme conditions of pH, moisture, salinity and high temperatures, which is recognized in the archaeological taphonomic field as resistance, that dental morphology is expressed to be genetically unique and unrepeatable in each tooth [4], and the tooth structure (metric and morphological) formed histoembryologically does not change or remodel itself as with the bone, excluding mechanical wear or attrition and accumulation of secondary dentine [1], and teeth, in many cases have become the only element to be able *per se* to provide biological and cultural information of an individual or a human population, which is possible due to: 1. High heritability and strong genetic control of dental morphology; 2. Little environmental influence; 3. Correspondence between the dental characteristics and geographical distribution; 4. Are easy to observe and record; 5. Permit to compare past with present

populations; 6. Have the ability to reflect the dietary habits of an individual and how they process food; 7. Reveal the conditions of health, age, sex, habits and functional occupational habits; and 8. Make evident technological and cultural development of a population [5-9].

Similarly, in the forensic context, the dentition is the accurate way to identify individuals whose death makes it difficult to distinguish by other processes (visual recognition, fingerprints, documents and clothing), which contributes to the reconstruction of individual and general osteo-biography (odonto-biography in the case of the teeth) [10]. That is, in anthropological and forensic contexts initially it is established general biology that links the individual as a member of a population with a specific gender, a certain age, ethnic patterns and a series of detailed physical characteristics including height and body proportions, commonly referred to as the basic quartet of identification. However, the diagnosis of sex is successful in 100% of the cases when the skeleton is complete and in good condition, when the individual is an adult and when the intra-group morphometric variability of the population, which the specimen belongs, is known. If only is available the skull, in an unknown population context or if the individual is immature, the degree of objectivity can range from 80 to 90%, taking into account that the age group between 15-18 years is the age limit to from which the sexual estimate more accurately appreciated [11].

## 2. Sexual dimorphism in human teeth

Human populations vary according to their phylogenetic origins as macro and micro-evolutionary patterns, ethnic, sexual characteristics (gender) and ontogenetically by age and also there are individual variations of each human being as a member of a species. That is why in the anthropological context, the population analysis is done through levels or scales ranging from general to particular and individual from the individual, the intra-group and inter-group, which is recognized as basic identification quatrain, which includes age, ethnic pattern, height and gender. The latter seeks from sexual variations on the shape and size of individuals, whether an individual is female, male or allophys, in which case it is not possible to determine either gender. This set of variations in ethnic and phylogenetic origin is known as sexual dimorphism. Contemporary humans are dimorphic, but less so than other hominids, with a body sexual dimorphism index of only 4 to 7%. However, taking into account the morphological features of post-cranial skeleton increases from 8 to 20% and that from the teeth increases 8 to 9%, mainly in the canine teeth, which are considered the most dimorphic teeth of living current human [6].

To determine the sex in the anthropological context from skeletal remains, there are different methods to analyze the metrical features or dimensions of the skull, which is known as craniometry, the morphological features or shape of the skull, including the glabella, the supra-orbital ridge, the nuchal crest, mastoid process and the chin, the bones of the skeleton as the jaw, hip, sacrum, scapula, clavicle, sternum, humerus and femur mainly, and metric and morphological features of teeth [10]. Through analysis of teeth, it is possible to study the sexual dimorphism of an individual from the patterns of dental development and eruption, the expression of a protein known as amelogenin, dental morphology and dental dimensions.

### 3. Dental morphology

The odontology or study of dental morphology, from the concept given by dental anthropology seeks to observe, record, analyze and understand the behavior of the expression (frequency and variability) of coronal and root morphology of human teeth. Overall, the teeth morphology is formed by a number of features that have been called dental crown and root traits, which constitute the enamel phenotypic forms expressed and regulated by the genome of an individual and a population during odontogenesis. These can be positive structures (tubercular and radicular) or negative (pit form and intertubercular) that have the potential to be present or not in a specific location (frequency) in different ways (variability) in one or more members of a population group [2,13-14]. Thus, the study of dental morphology integrates different disciplines such as physical anthropology, biology, dentistry, paleontology and paleopathology, with the aim of generating markers from the teeth of both primitive and the modern human being, characterizing the taxonomy of the human species within the anthropological context and following a crucial role in the processes of identification for forensic purposes, since the teeth and dental morphology is a highly heritable characteristic, that have the potential to establish classifications, allow comparison of the primitive with the modern restoration materials, are stable in time and have a fairly high state of preservation compared to the bone material [15].

#### 3.1. Non-metric dental traits

The dental morphological or non-metric characters, are also called discrete, discontinuous, quasi-continuous or epigenetic traits [7] and they are observed, recorded and analyzed with scientific evidence of high taxonomic value, frequency, variability, bilaterality, sexual dimorphism and correspondence between features, conditions that allow them to be used in the estimation of biological relationships among populations by comparative analysis of human past and present groups, to try to clarify the historical, cultural and biological macro-and micro-evolution, leading to the understanding of displacement, migration paths and contacts that led to the settlement and ethnic variation of humanity. All existing studies indicate that dental morphological traits have a strong genetic component if one takes into account their occurrence or frequency and the expression or gradation [6].

The analysis of dental morphology, parallel to the genetic observation is based on the frequency and variability of non-metric dental traits through the phenetic method (the phenome is the physical expression of the genome) applied especially for the comparison of population frequencies i.e. a dental morphological feature is the representation of an elementary and indivisible taxonomic trait known as phen (phenetic variation unit) which, as a feature discrete dichotomy is expressed by the presence - absence initially described by A. Hrdlicka in 1920 after observing the characteristic shovel-shaped incisors concluding that when a feature was present it took different forms, ranging from minimal forms of expression to maximum levels. It is for this reason that for the population phenetic analysis is used stable dental crown traits and high genetic component, which determine the grade of variations or degrees of expression. For this purpose, must be selected samples of at least

100 individuals per population phenotypically different from the standpoint of inter-group. In this way are found the more effective degrees of a taxonomic trait selected in order to obtain inter-group markers in a specific population [6].

Until present, there are over 100 dental crown traits and root that have been recognized in the human dentition, but in most worldwide research are used no more than 17 features, mainly those located in the crown of incisors and molars of both dentitions. The observation of these features is done through different methods reported in the literature, excelling ASUDAS method [16] developed since 1940 by A. Dahlberg from standard dental plates and transferred in 1981 to C. G. Turner II at Department of Anthropology of the Arizona State University, hence its name.

However, different authors have developed their own monitoring systems for different morphological features, both for deciduous and permanent teeth, such as methods of K. Hanihara [17], A. Zoubov [15], K. Alt [13], P. Sciulli [18], and F. Grine [19], among others. These systems generally allow observation beyond the dichotomy of presence/absence and promote inter-observer reproducibility to generate data that represent physical minimum and maximum expression of a trait and varying degrees of expression between these two reference points.

To make the correct observation and grading of dental morphological traits are used models of plaster casts of dental impressions in polymeric materials with high dimensional stability from individuals of a particular population. The observer, previously calibrated, learn to handle morphological systems used on plaster models with the aid of a stereomicroscope and a fine tip dental explorer. Generally, from the statistical point of view, estimating the degree of agreement takes into account the criteria of inter-observer (observer vs. gold standard) and intra-observer (observer vs. observer) denoted by C. R. Nichol and C. G. Turner [20]. To define the dental morphological features, mainly expressed in the crown of the tooth will be grouped by the type of teeth (incisors, canines, premolars and molars), with the aim of demonstrating their sexual dimorphism expression (frequency), variability (gradation) bilateral symmetry, correspondence between biological traits and population distances. To name each tooth is possible to use two types of nomenclature, FDI (World Dental Federation) and anthropologic nomenclature. In the FDI nomenclature, 32 permanent and 20 deciduous teeth are divided into hemi-arches and each hemi-arch is named with a number, 1 for the upper right hemi-arch, 2 for the upper left hemi-arch, 3 for lower left hemi-arch and 4 for the lower right hemi-arch. The first digit representing a tooth indicates the hemi-arch where the tooth is located. In the case of primary teeth quadrants are represented by the numbers 5 to the upper right hemi-arch, 6 for the upper left hemi-arch, 7 for the lower left hemi-arch and 8 for the lower right hemi-arch. For example, for tooth number 11, which is a central incisor, the first 1 corresponds to upper right hemi-arch, the second 1 corresponds to the position from mesial to distal, so it is a permanent right maxillary central incisor. In the case of anthropological nomenclature, the teeth are represented by an alphanumeric code where the dental arch is represented by the "U" for upper arch and "L" for the lower arch, the tooth class is named with the same initial, "I" for incisors, "C" for canines, "P" for premolars and "M" for molar, and if in a class of two types of

teeth will be numbered according to position. This corresponds to the UI2 maxillary lateral incisor. For the primary dentition is used the same code but are in lowercase alphabetic characters. Since in the anthropological context of bilateral symmetry classes and types of teeth are fully established, there is no discrimination if left or right.

### 3.1.1. Incisors

In human primary and permanent dentition, there are two types of incisors, upper central incisors UI1 (11 and 21) and LI1 lower (31 and 41), located on either side of the midline, and the upper lateral incisors UI2 (12 and 22) and LI2 lower (32 and 42), which are available immediately distal of the central incisors. These, along with the canines are the group of anterior teeth, whose most basic functions are the arrest (along with the lips), the incision and the partition of food into smaller pieces so they can be chewed by the posterior teeth. They also have an important role in functions of the human being as passive participation in phonation and a complex social component such as an active part of the aesthetic facial [21-23]. Both in primary and permanent incisors there have been reported several dental crown traits like winging (rotation of one or both maxillary central incisors with respect to the midline), crowding (crowding of the incisors), shovel-shaped (development of the mesial and distal marginal ridges), double shovel-shaped (relative development of the buccal marginal ridge setting up a sort of pit vestibular), dental tubercle (crest or tubercle which appears in the region of the cingulum on the lingual surface), interruption groove (across the cingulate sulcus to reach the enamel-cement, often continues into the root), curvature of the labial surface (convex in the middle third of the labial surface of the crown surface viewed from the incisal) and vestibular contour (contour shape of the incisors in relation to the mesial and distal marginal ridges, the incisal and cervical margins) [24-27].

This chapter will be described the shovel-shape as a feature of great forensic and anthropology interest.

- Shovel-shaped

It consists of the marked development of the mesial and distal marginal ridges and palatal configuration of the deep pit in a triangle. Is seen mainly in the upper central incisors, although the feature can be expressed in the upper lateral and less frequently in both lower incisors, however, in the population analysis only the central incisor is used as inter-group marker to be a polar stable tooth, according to the statement of the theory of morphogenetic fields of P. Butler [6]. The observation method was proposed by A. Hrdlicka in 1920, the plate was developed by A. Dahlberg in 1956 and the current classification was made by G. Scott in 1970. The reference plate in the ASU system is UI1 ASUDAS shovel. The blade shape is observed in the lingual surface of central incisors and upper and lower side, formed by the palate or lingual fossa and mesial and distal marginal ridges [16]. The dichotomous expression (presence/absence) describe from a flat palatal surface to a marked development of the marginal ridges. For the taxonomic analysis are only taken into account the marginal ridges and not the depth of the concavity since the latter is quite independent and has negative correlation with the development of the ridges. However, some authors take into



account the depth of the pit palate and indicate that there is shovel-shaped from 0.5 mm in depth, if less does not express the trait [28].

The worldwide variation of this marker in the central incisors ranges from 5% in Europe to 100% in Mongoloid origin populations. Since the time of early African hominids it has been showed the development of shovel-shaped incisors. In Asia this trait is clearly expressed since the early hominids. According to paleontological information, exists a geographical boundary between the West, with low frequencies of shovel incisors, and the east with high frequencies of this trait [6], which is an effective boundary between the European and Mongoloid populations (Asian and American) [15].

K. Hanihara [17] developed the Mongoloid dental complex from five dental morphological traits (including shovel-shaped upper central incisors) that had a high frequency and distribution of which were quite useful in analyzing the affinities between different populations. Thus, for this trait expression there are differences between Negroid, Caucasian-American and Mongoloid origin population groups. In particular, significantly higher frequencies are shown by Japanese, Pimas and Eskimos, and slightly less in Ainu. T. Hanihara [28] found a prevalence of 9.2% in Japanese, 33.3% in blacks and 27.7% in white Americans, while C. G. Turner in (1984) observed this trait in 98.8% of sinodontes, in 99.8% of the South American aborigins and in 29.4% of northeastern Europeans. The same C. G. Turner II [29-31] related the results of the frequencies of some morphological traits of populations of Asia, Oceania a Polynesia and Hispanic American populations, and in this way he showed that the Americas were populated via the Bering Strait. Similarly, the geographic distribution of traits according to different human groups that make up the dental complex East Asian Mongoloid allowed Sinodonte subdivide the pattern in the north, characterized by the addition and enhancement of some features (like the shovel incisors), and the pattern Sundadonte south, typified by the retention of an ancestral condition and simplification of certain features within the protruding low frequency of shovel-shaped. Would be those who crossed the Bering Sinodontos some 14,000 years ago who populated the Americas in three consecutive waves, being the east of Lake Baikal the last home of the indigenous peoples of North and South America. Therefore, all pre-Columbian indigenous groups are part of the pattern Sinodonto at the Mongoloid dental complex. For this reason, the shovel shaped central incisors are present in almost 100% of pre-Hispanic and American Indian populations in modern American populations as evidence of the process of miscegenation [24-27].

### 3.1.2. *Canines*

Anatomically, the canines have bulkier root in the palatal-lingual direction and longer than other teeth, this allows a strong anchoring in the alveolar bone with abundant and dense compact bone and confers high resilience to the forces generated during the chewing cycle during which dampen excessive horizontal and deleterious forces are generated during lateral movements to protect the back teeth, an action that depends equally from its high capacity to nociceptive sensory stimuli during the action of mastication muscles. Basically, this protection is mediated by the occlusal relationship between the canines, which, upon

the lateral movement of the lower canines jaw slide over the top, a function described in the literature as "canine function" or "canine key," to produce disocclusion of posterior teeth. Hence, the canines are considered "milestones" or "signposts" of dental occlusion. These consist of two maxillary and two mandibular teeth localized each one in a hemiarch between the incisors and premolars group. The upper canine crown UC (13 and 23) presents the labial surface in a diamond shape, with the incisal edge acute (formed by the mesial and distal cusp slopes that meet at a cusp vertex) and rounded in the cervical region. The palatal surface has a central crest elevation or extension from the cingulum to the cusp apex, and two marginal ridges, mesial and distal, which constitute the central ridge with two mesial and distal palatal fossae respectively. The lower canines LC [33, 43] have a longer narrower crown, and lower bulge than the upper canines. From the buccal view, mesial contour is relatively straight while the concave distal cemento-enamel junction, but convex in the distal cusp slope. On the lingual surface mesial and distal pits are less noticeable than in the upper, and the cingulum is more blunt than the upper canine and the mesial and distal halves of the crown are more symmetrical. Permanent canines are the only teeth in its class in both the maxilla and mandible, where they are located at the four corners of the dental arches between the lateral incisors and first premolars, what constitutes an important support of the facial muscles. Phylogenetically, morphology and dimensions have been associated with capture functions, excavation, cutting, boring, defense, attack, sexual dimorphism and social power [21-23].

In the case of the canines very few studies have been conducted. P. Butler in 1939 suggested that the morphology and size of the premolars are controlled by the canines ("caninization" of the first premolars) and molars ("molarization" of the second premolars) during tooth morphogenesis, while A. Dahlberg in 1945 held that the premolars had a morphogenetic field independent and exclusive to them. In short, none of the two theories have been proven due to the exclusion of the premolars of anthropological and genetic research (largely due to ignorance of evolutionary and embryological behavior of these teeth), being relegated from the global dental morphological classifications (dental complex) and limited their study to the description of the meso-distal and bucco-palatal or bucco-lingual dimensions [32].

Worldwide research on this topic has covered many of the current populations and a number of past populations, focusing mainly on the description of the frequency and variability of dental morphological features located in incisors and molars, leaving aside the morphology of canines and premolars. However, the descriptive and quantitative analysis of the morphology of the canines has allowed hominids to be taxonomically classified, so that has contributed to the estimate of the evolutionary origin of the genus *Homo* and understanding the geographical distribution of past and modern human groups. In primates, the reduction in canine size and degree of sexual dimorphism is related to the size of the crown and the simplification of the morphology, which received direct selective pressure from the acquisition of the erect position, the bipedalism, reduced facial prognathism, reducing the size of the dental arches and microdontia generalized morphological conditions specific to humans [33-35].



In the temporary and permanent canines, according to reports in the literature, it is possible to study various dental crown traits such as shovel-shaped (relative development of the mesial and distal marginal ridges of the lingual surface), double shovel (relative development the mesial and distal marginal ridges on the labial surface), labial convexity (convexity degree of vestibular), slot interrupt (through the cingulate sulcus of the upper canines up to the cement-enamel junction), dental tubercle (crest, tubercle or peak that appears in the cingulate region of the lingual surface), canine mesial ridge (mesial crest variation), distal accessory ridge (small accessory crest that appears on the distal-incisal) central peak (central area shown in palate), palatal fossae (two graves, mesial and distal, which appear in the palatal surface of the upper canines) and lingual fossae (two graves, mesial and distal, which appear on the lingual surface of the lower canines) [36]. The canine mesial ridge and the distal accessory ridge are population dental traits important within anthropological and forensic contexts.

- Mesial canine ridge

The expression is observed in the variation of the mesial crest of the upper canines. The canine mesial ridge, the protostylid or "Bushman canine" was described by Morris in a population of Bushmen in South Africa [37]. The recording of this feature is done by ASU Bushman Canine plate [16], which describes such a way that the mesiolingual edge of the upper canine, similar in size to distolingual, can overcome and form a fold distal approximately 2/3 below the incisal surface, due to its junction with the dental tubercle.

- Distal accessory ridge

It is observed as the presence and expression of a small accessory crest that appears on the distal-incisal region of upper and lower canines. The record of this trait was performed by UC DAR ASU board. This has been one of the most worldwide studied morphological crown dental traits of canines [16]

### 3.1.3. Premolars

In the case of the premolars are very few studies conducted. P. Butler in 1939 suggested that the morphology and size of the premolars are controlled by the canines ("caninization" of the first premolars) and molars ("molarization" of the second premolars) during tooth morphogenesis, while A. A. Dahlberg in 1945 held that the premolars have a morphogenetic field independent and exclusive to them. In short, none of the two theories have been proven to the exclusion of the premolars of anthropological and genetic research (largely due to ignorance of evolutionary and embryological behavior of these teeth), being relegated from the global dental morphological classifications (dental complex) and limited their study to the description of the meso-distal an bucco-palatal or bucco-lingual dimensions [38].

The premolars consist of four maxillary and four mandibular teeth located in pairs on each hemiarch between the canines and first molars. The higher UP1 (14 and 24) and UP2 (15 and 25) have two cusps of similar size and usually two roots, especially the first premolar. The

occlusal surface has an oval contour characterized by well-defined grooves directed from mesial to distal. The lower LP1 (34 and 44) and LP2 (35 and 45) are uniradicular, and have three cusps (second premolar) that form a rounded occlusal contour with a groove, which is often interrupted. Broadly speaking, the premolars are a transition from the canine (buccal cusp high and pointed cone), which increase the occlusal contour from the first to the second, i.e. "molarization" thanks to the development of prominent marginal ridges and increased height of the palate or lingual cusp [21-23].

In the literature have been reported and described as 12 dental crown traits, such as the mesial accessory ridge (small ridge located toward mesial of accessory sagittal grooves), distal accessory ridge (homologous mesial accessory crest, but is located towards distal of the buccal cusp of the maxillary premolars), mesial interstitial tubercle (tuber apex or blunt cusp mesial region between the buccal and palatal cusps of the premolars), distal interstitial tubercle (or Terra, cusp or tubercle apex blunt cusp between the distal buccal and palatal cusps of the premolars), tricuspid bicuspid (developed disto-lingual cusp is smaller and closer to the palatal cusp), hypostyle (small cusp with vertex set which usually appears between the buccal cusp and disto-lingual cusp), vestibular sulcus (odontoglyphic feature that is the distal groove projecting from the distal pit to buccal), central ridge (or ridge of enamel bridge that connects the buccal cusp with meso-lingual cusp), meso-lingual sulcus (odontoglyphic trait that describes the path that part of the hole and crosses the mesial marginal ridge towards the same side of meso-lingual), disto-lingual groove (odontoglyphic trait that corresponds to groove originate from the distal marginal ridge and crosses the same side of the distal-lingual direction), lingual cusp number (number of cusps that can occur in the region of first premolar lingual) and groove pattern (configuration of the grooves and the contact pattern of the cusps of the occlusal surface of the lower premolars) [39].

The frequencies reported by G. Giron et al [39] show the trend of the first premolar to have a low frequency of mesial accessory crest and a moderate expression of distal accessory ridge, two cusps with constant presence, absence of buccal grooves and lower frequencies of interstitial tubercle mesial and distal, while the second premolars often show high expression of the mesial and distal accessory ridges, and the interstitial tubercles mesial and distal (although the expression of this trait in the first premolars in the latter is greater); likewise always have two cusps and no developmental grooves vestibular are expressed. In the case of the lower premolars, the first is characterized by no vestibular developmental grooves, only one lingual cusp present, have a high central peak expression, mesiolingual groove and a U-groove pattern, in contrast to the configuration of the occlusal morphology of lower second premolars which is very different, given the low expression of meso-and disto lingual groove, the absence of central ridge and vestibular groove, the high frequency of a single lingual cusp and groove U pattern.

### 3.1.4. Molars

The molar teeth consist of four maxillary and four mandibular teeth located in pairs on each hemiarch distal of the canines. The UM2 second molars (55 and 65) and lower LM2 (75 and

85) are totally different from the first molars UM1 (54 and 64) and LM1 (74 and 84) and have a shape and morphological features very similar to the first permanent molars. The first molars are not taken into account because, although their morphology is very variable, they are more like a premolar than a molar. Permanent molars are six maxillary and six mandibular, which are located distal to the second premolars. UM1 first upper (16 and 26) and lower molars LM1 (36 and 46) and UM2 upper (17 and 27) and lower LM2 second molars (37 and 47) at first glance are very similar, but under analysis of dental anthropology, they have significant differences in the expression of dental crown traits, which is why the same correspondence between one and other tooth will permit to understand the genetic and environmental influences, both by their frequency the expression. UM3 third molars (18 and 28) and LM3 (38 and 48) are not taken into account for the study of dental morphology since this tooth has a strong evolutionary trend toward the disappearance, which is evident given the high frequency of agenesis and atypical forms [21-23].

In the molars the traits that have been more frequently studied are Carabelli trait (pit or cusp in the meso-lingual cusp of the upper molars), hypoconid reduction (downsizing disto-lingual cusp of the upper molars), metaconulo (small cusp between disto-buccal cusp and disto-palatal maxillary molars) groove pattern (contact configuration of the cusps of the molars), number of cusps, elbow crease (the meso-lingual cusp is directed toward the central fossa in lower molars), protostylid (pit or buccal cusp on the buccal developmental groove of the mandibular molars), cusp 6 (cusp between the disto-buccal cusp and disto-lingual surfaces of lower molars) and cusp 7 (cusp between the meso-lingual cusp and disto-lingual surfaces of lower molars) [24-27].

The features to be the focus of the discussion in this chapter are the most studied in worldwide populations, as in the case of the cusp of Carabelli, protostylid and groove pattern.

- Carabelli trait

It is located on the palatal surface of the apex of the mesopalatal cusp of second primary molar and the first and second upper permanent molars. The variability of expression ranges from a small pit, through a groove in a "V" or "Y" up to the formation of a cusp. The first observation scale was developed by A. Dahlberg in 1956. One of the methods of measurement in the primary dentition was designed by F. Grine [19], while for permanent teeth are usually used the ASUDAS method developed by C. G. Turner [16].

Carabelli trait is considered worldwide as a Caucasoid trait. T. Hanihara [28] found low frequencies of this trait in Japanese and higher in black and white Americans, finding that this trait distinguishes Caucasoid populations of Asian and that in the latter predominate the groove and pit forms, whereas C. G. Turner [29] found significant expressions in sinodontes, South American indigenous and northeastern Europeans.

In modern American populations, N. Aragon et al [27] in a sample of an indigenous population in Colombia found that in both dentitions dominated groove and pit forms (grades 1 and 2 in deciduous, grades 1 to 4 in permanent teeth) than cusp form (degree 3

and 4 in deciduous, grades 5 to 7 in permanent). However, and according to the expression dichotomy, although the cusp of Carabelli is considered to be present in the sample should not be associated as a product of mixing of Caucasoid origin, since the intermediate grades pit expression is considered present and is characteristic of American Indian populations. J. Rocha et al [26] in a population of Afro-Colombians in Colombia found significant frequencies of cusp expression, which is characteristic of populations of African origin and that according to A. Zoubov [15], conform southern Caucasoid dental or western equatorial complex. In a mixed population of Colombia, S. Moreno et al [24] reported the higher frequencies in grades 0, 1 and 2 with a higher prevalence of grade 1 (fovea present). L. Aguirre et al [25] indicated that the cusp of Carabelli is not sexually dimorphic, it is expressed predominantly bilaterally and furrow and grave forms of tubercle and cusp forms, both as permanent dentition, which indicates that there is ambivalence in discrimination population for this trait. The correlation of the prevalence between both dentitions indicates a strong genetic control for the expression of it.

- Protostylid

This paramolar cusp is antagonist to Carabelli cusp that varies from a groove to a free apex cusp on the vestibular surface of the meso-vestibular cusp. Also is often expressed as a fovea or pit on the buccal developmental groove called Point P or vestibular foramen caecum. A. Dahlberg developed the reference plate in 1956 [6], but at present the method to observe it in permanent molars is ASUDAS [16].

A. Zoubov [15] defines americanoide protostylid as a feature due to the low frequency of expression in the populations of Europe, Africa and Asia the peculiarity of the high prevalence of point P or foramen caecum American populations. K. Hanihara [40,41] indicated that the expression of protostylid cusp is rarely present in different populations, occurring rarely in modern human groups, most Asians, which allow to differentiate the dental complex of Caucasoid and Mongoloid Negroid. In primary teeth is commonly observed pit expression and some degree of mild elevations. N. Aragon et al [27] found this feature absent from the sample in the case of primary dentition and present with groove expression in the permanent dentition in an indigenous Colombian sample. The interesting thing about this feature is the high frequency of grade 1 (pit or foramen caecum) in primary teeth, and that although in permanent teeth is often the development of the distal row from vestibular sulcus, is a preserved expression of the form pit. J. Rocha et al [26] described the protostylid as absent in the sample of African descent, but they highlight the high frequency of grade 1 which again suggests the possibility of interbreeding with indigenous peoples, in the same way as S. Moreno et al [24] in their study in a mixed population of Caucasoid Colombians reported high frequency of grade 1. L. Aguirre et al [25] in their study observed that the protostylid reflects that the population studied has a significant retention of American Indian dental complex, as evidenced by the high frequency of grade 1, explained as a pit on the buccal developmental groove that separates meso and disto-buccal cusps. These authors state that in modern American populations the protostylid pit form predominates in both deciduous and permanent dentition.

- Groove pattern

The groove pattern of the second temporary molars and first permanent molars describes the configuration of the contact of the cusps and the number of them. The classic pattern is Y or "Driopitecino" originating in the past Asian populations, and + X or "cruciform" are considered as reductions frequently observed in Caucasoid groups [6]. N. Aragon et al [27] report that the behavior of the number of cusps and groove pattern, present for the case of deciduous dentition Y6 and Y7 predominantly configuration, where the groove pattern and has a strong genetic control kept from past Asian populations that inhabited the Americas through Beringia from which derive the pre-hispanic Amerindian and present populations. In their study of African descent, J. Rocha et al [26] found that the behavior of the groove pattern and number of cusps shows the predominance of +5 and +6 configuration, shown as a reduction driopitecino pattern characteristic of non-Mongoloid populations. The frequencies of the configurations X6 and Y5 suggest some genetic influence product of miscegenation of Caucasian and indigenous groups. L. Aguirre et al [25] reported that expression of the grooves intercusp contact was given by the Y pattern for the second temporary molars and + pattern for the first permanent molars, indicating that it may be because the primary dentition has a strong genetic control and has therefore retained the original Driopitecino pattern of ancestral Asian populations. In the case of the first permanent molars, one can assume that the miscegenation processes mark a trend toward + pattern, which is characteristic of Caucasian populations.

## 3.2. Sexual dimorphism of dental morphological traits

### 3.2.1. Incisors

Regarding the incisor teeth, in the literature can be found a general consensus of the absence of sexual dimorphism in the shovel form, taken into account in this chapter that this is one of the most studied dental traits for its importance in the discrimination populations according to the dental complex. However, in the dental literature, there are several reports describing morphological differences according to sex of individuals and has great clinical importance in the area of aesthetic and cosmetic dentistry for diagnostic procedures of smile design [42]. Thus, the proximal contours, dental angle, incisal edge and the emergence profile are important for the teeth in harmony with the shape of the face [43-44].

Within the body outline the face has an aesthetic requirement that is extremely important as the aesthetic composition of the human as psycho-socio-cultural being, and teeth are part of the integral and harmonious appearance of the morpho-functional composition, including within the aesthetic-affective manifestations recognized as smiling, laughing, kissing and oral-facial gestures being teeth beyond the biological part of the smile. Their disposition in the arches are in compliance with the support function of the soft tissues, influencing the position taken by the facial muscles, which contribute to the determination of facial traits that are involved in the character and personality. For this reason, the face and facial expression are influenced by genetic inheritance and environmental factors, within which are the rounded, square or triangular shape of upper central incisors [45-47].



The analysis of these and other structures that make up the stomatognathic system of human groups, constitutes a fundamental starting point for micro-and macro-historical processes and reconstruction of the ethno-demographic origin of the current populations, for biological, functional and aesthetic dental diagnosis prognosis and treatment plans, and for forensic identification methods using facial reconstruction techniques.

Williams in 1914 -cited by L. Ibrahimagi et al [48]- postulated that the inverted form of the upper central incisors is related to the shape of the face, which is applicable in dental settings for harmonization of aesthetic oral rehabilitation procedures, anthropological (morphological grounds for facial reconstruction procedure) and forensic (individualization during the identification process). Frush and Fisher -cited by M. Waliszewski [49]- proposed the concept of “genetic tooth aesthetic form of the patient”, which indicate that the shape of the teeth due to factors such as sex, age and personality of the patient, which coined the term dentogenic to name the relationship between these variables. But there is no consensus in the various literature reports. Wright and Brodbelt, -cited by L. Ibrahimagi et al [48]- reported that the shape of the upper central incisors and the shape of the face corresponds to a situation that had already expressed by the same Ibrahimagi et al [48] in disagreement with the theory of Williams mainly because the mix of ethnic groups in the population and the infinite possibilities of combining forms of differently shaped face and the upper central incisors shape had selectively affected the genetic correlation between these two variables. S. Berksun et al [50] and S. Wolfart et al [51] reported that it is possible to define the correlation of the shape of the face and shape of the teeth due to ethnic ambiguity of worldwide reports. Thus, D. Acosta et al [52] conducted a study in Caucasian population where correlated features as facial contour with the shape of the contour of the upper central incisors, finding that an oval facial shape corresponds to the oval shaped upper central incisors, which does not occurs with square and triangular shapes. Likewise, although there is significant sexual dimorphism in the shape or contour of the face or the shape of the contour of the upper central incisors, the authors conclude that women had more prevalent oval and round shapes, while than in men predominate oval and square shapes.

### 3.2.2. *Canines*

The study of canine morphology has been used to understand the evolution of sexual dimorphism in the socio-ecological and phylogenetic development of primates. Sexual dimorphism is defined as an intra-specific difference between men and women, which can be studied from the somatotype of the individual, the size and dental morphology, and correlated with intra-sexual patterns of competition [53,54]. Ontogenetic mechanisms exist that cause morphological differences between males and females during primate evolution. The ontogenetic changes in these processes lead to the existence of sexual dimorphism associated with the size and evolutionary response to various factors including territoriality, competition and the distribution of resources [55].

Despite the changes in the size of the canines during hominid evolutionary line between male and female individuals, morphology has not suffered sexual dimorphism given its high intra-species preservation, related primarily to the canine is the one of a kind and has

its own highly conserved morphogenetic field, which is also supported by the bilateral symmetry of dental morphological traits [35].

P. Butler since 1937-cited by van Reenen et al [56] - from his studies in Cenozoic mammals under the concepts of Huxley and De Beer, formulated the theory of morphogenetic fields in which the ectomesenchyme that migrates within the first arch is programmed to form a single tooth family that later modify its form by the action of external factors. In 1945, A. Dahlberg -cited by van Reenen et al [56] - adapts the concept of morphogenetic fields in the human dentition and represents the existence of four rather than three dental fields, and introduces the premolar class as a field. While it should be noted that the deciduous and permanent molars have similar morphological characteristics that allow them to be linked to the same morphogenetic field, in man and in most mammals premolars differ markedly from their predecessors, the molars, and this is why premolars could be considered as potential molars deviated the field development by the molar (molarization) and were influenced by proximity to canine field (caninization). Later, G. C. Scott and C. G. Turner [5] suggested that gradients expressed in the morphogenetic field theory and the model proposed by Osborn clones theory in 1978, in which, as ectomesenchyme migrates into the first arc, and is differentiated into three clones, incisor, canine and molar, have scientific evidence and do not exclude each other.

Today, advances in molecular biology have allowed to mark the factors that control the morphogenesis of teeth from epithelial-mesenchymal relationships, in fact, the morphogenetic field corresponds to a specific place where a number of factors and proteins development are expressed and inhibited in the formation of a specific tooth, so bilateral symmetry and the absence of sexual dimorphism in the expression of dental morphological features of the canine teeth is associated with temporary and permanent mainly to the canines are the teeth of the morphogenetic field gradient, and as the central incisors and first molars for their respective fields, they are in the teeth with higher degree of conservation according to gene expression and lower influence of the environment from the viewpoint of macro-evolution.

### 3.2.3. Premolars

In the case of the premolars, the shape of its contour and dimensions have been extensively studied as a tool for building the phylogeny of hominids from small samples of Australopithecines, Pliocene hominids, and Homo of low and medium Pleistocene [57], because from the standpoint of dental anthropology, the evolutionary value of morphology and dental odontology is based on the strong genetic control of frequency and variability, which allows to establish direct links between the anatomical structure of the teeth, including premolars, and relationship between populations. However, in the literature are few studies on morphology of premolars and there have not been studied all the morphological features or have used different methodologies, based on the likelihood that human groups that present a similar dental morphology and dimensions can be interrelated, in fact, the shape and dimensions exhibited by a tooth-set the similarity or dissimilarity of morphological variation and genetic metric of a common ethnic trunk [58]. This will make it

possible to infer macro-evolutionary processes that have demarcated the settlement, in this case a specific region such as the southwestern Colombia.

Based on the frequency and variability of morphological features obtained in this study, graphically presents the morphology of the occlusal surface of a sample of mixed Caucasoid traits of the first and second upper and lower premolars. To demonstrate the behavior of the expression of the morphology of the premolars has important clinical implications (in the dental context) whenever the functional morphology plays a role in inter-occlusal relationships during the various functions of the stomatognathic system [21-23] and ethnic (in the anthropological and forensic contexts), because there is ample evidence in the literature analysis tooth morphology contributes to the establishment of the basic identification quatrains (osteography or odontography) specifically in the estimation of the age, sex and ethnic pattern [59,60].

Regarding the theory of morphogenetic fields made by P. Butler, in which the morphology of the deciduous and permanent teeth due to a progressive gradation from the incisors to the molars, premolars can be considered as potential deviated molars from field development influenced by the molar (molarization) and that, as stated previously, the field were influenced canine (caninization), so that the conformation of the occlusal table from the development of cusps and the expansion of meso-distal and bucco palatal or bucco lingual diameters. However, the deciduous molars have the same characteristics of permanent molars (for which they are associated with a single morphogenetic field), while the premolars differ markedly from their predecessors, the molars. This occurs in most mammals, including man, so A. Dahlberg adapted the concept of morphogenetic fields in the human dentition and justified the existence of four fields, where the premolars molars have their own field. This theory was supported by Scott and Turner, indicating that the shape and size of the premolars is not "obviously" equal to that of the molars. Another aspect that supports this theory, is an evolutionist, in which the premolars were reduced in number, the first placental mammals had four to five premolars per hemi-arch, while the primates reduced to three premolar teeth formula for hemi- arch in the Primate. In humans, were preserved two premolars per arch corresponding to the last two ontogenetically, hence they have a greater resemblance to the molars than to canines [56].

While some points of the theory of morphogenetic fields are still of extensive study and debate, in the context of dental anthropology have been conducted several studies that have allowed the characterization of morphology, so that large morphological and metric differences have been established with the molars, as the organization of the occlusal table and the number of cusps [38], concluding from the study of the frequency and variability of dental morphological traits that premolars have bilateral symmetry, there is morphological correspondence between the first and second premolars and have no sexual dimorphism [39].

#### 3.2.4. *Molars*

With respect to the molar teeth, it is worth noting that these are the teeth which dental morphological features have been extensively studied in human populations, past and

present. L. Aguirre et al [25] studied the correlation of morphological dental traits as cusp of Carabelli, protostylid and groove pattern between the second molars and first permanent molars of mixed Caucasoids, finding that in the first two features there is correspondence of expression and variability, bilateral symmetry and absence of sexual dimorphism, suggesting a strong genetic control. In the case of intercuspation contact pattern, there was no correspondence in the frequency and variability of the trait, which suggests that the deciduous teeth, because at higher genetic control, have retained the primitive Y or "dryopithecine " while permanent teeth, perhaps by environmental influences or by the miscegenation, tend to set a more Caucasoid + or "cruciform" pattern. This great similarity in dental morphology between the second deciduous molars and first permanent molars, reflects a common origin within the morphogenetic field, not in vain, researchers such as P. Butler and A. Dahlberg indicated that the tooth gradient deciduous and permanent molars is the second deciduous molar, since it retains the basic configuration of the contact pattern, typical of early hominids [2]. Thus, various studies have supported the theory of morphogenetic fields [61]. Later, A. Ocampo et al [62] conducted a study to determine the correlation of Carabelli, hypoconid, bridge of enamel metaconule, protostylid, elbow crease, groove pattern, number of cusps and cusp 6 and 7 between the upper and lower second molars (UM2 and LM2], the upper and lower first molars (UM1 and LM1] and second upper and lower molars (UM2 and LM2], in mixed populations of Caucasian, Afro-descendants and Colombians indigenous. Colombian indigenous are characterized by UM1/UM2/LM1/LM2 that have a high correlation with um2/lm2 in MCDT whose expression involves cusp formations (Carabelli, metaconule, groove pattern and cusp 6], suggesting high genetic conservation and low environmental influences, since these features are formed during early morphogenesis. This situation is observed in the Caucasian mestizos, but the expression of some morphological features indicates that there is more miscegenation, which may be evident in groove pattern variation from Y to +, which showed a moderate correlation. In mixed Caucasian and Afro-Colombian descent, significant correlations were observed in the same morphological features, which can be associated with their settlement in the same geographic area (southwestern Colombia) because they are part of the ethno-historical and macroevolutionary processes of miscegenation [62] (Tables 1 and 2].

Teeth	Traits	Frequency (%)	Sexual dimorphism Mann-Whitney U $p < 0.05$	Bilateral simmetry Wilcoxon $p < 0.05$
UI1	Winging	37.2	0.619	-
UI1/UI2	Crowding	25.4	0.481	0.428
UI1	Shovel-shape	40.1	0.697	0.157
UI2	Shovel-shape	40.9	0.269	0.829
UI1	Double shovel-shape	5.6	0.269	1.000
UM1	Carabelli trait	52.2	0.269	0.808
UM2	Carabelli trait	7.2	0.879	0.689
UM2	Hipocone reduction	65.5	0.198	0.763
LM1	Pattern cusp	3.0	0.826	0.439

Teeth	Traits	Frequency (%)	Sexual dimorphysm Mann-Whitney U $p < 0.05$	Bilateral simmetry Wilcoxon $p < 0.05$
LM2	Pattern cusp	7.3	0.033	0.166
LM1	Cusp number	72.4	0.630	0.491
LM2	Cusp number	40.5	0.768	0.739
LM1	Deflecting wrinkle	59.5	0.312	0.025
LM1	Protostilyd	4.2	0.072	1.000
LM2	Protostilyd	7.8	0.272	593
LM1	Cusp 6	7.8	1.000	0.271
LM2	Cusp 6	1.4	0.495	0.414
LM1	Cusp 7	15.9	0.495	0.899
LM2	Cusp 7	3.0	0.821	0.655

**Table 1.** Relative frequency of the non-metric dental traits al the colombian afro-descendants population

Teeth	Traits	Frequency (%)	Sexual dimorphysm Mann-Whitney U $p < 0.05$	Bilateral simmetry Wilcoxon $p < 0.05$
UI1	Winging	45.6	0.373	-
UI1/UI2	Crodwing	29.3	0.011	-
UI1	Shovel-shape	90.7	0.750	1.000
UI2	Shovel-shape	81.5	0.165	0.046
UI1	Double shovel-shape	20.9	0.041	0.000
UI2	Double shovel-shape	19.0	0.025	0.010
UM1	Carabelli trait	49.0	0.510	0.045
UM2	Carabelli trait	6.3	0.610	0.776
UM2	Hypocone reduction	29.4	0.405	0.527
LM1	Protostilyd	2.6	0.028	0.527
LM2	Protostilyd	4.2	0.550	0.083
LM1	Deflecting wrinkle	41.1	0.497	0.561
LM2	Deflecting wrinkle	0	0.658	0.564
LM1	Cusp pattern	17.9	0.134	0.063
LM2	Cusp pattern	12.8	0.043	0.564
LM1	Cusp number	34.8	0.704	0.180
LM2	Cusp number	36.3	0.118	0.564
LM1	Cusp 6	38.3	0.231	0.935
LM2	Cusp 6	12.5	0.299	0.063
LM1	Cusp 7	2.8	0.229	0.655
LM2	Cusp 7	0	1.000	1.000

**Table 2.** Relative frequency of the non-metric dental traits al the comtemporany colombian indigenous population



### 3.3. Statistical analysis of sexual dimorphism

Since dental morphological features are analyzed according to their expression (dichotomy presence/absence) and variability (gradation), at the time to categorize the variables for the descriptive statistical analysis, each level of expression of morphological traits constitutes a qualitative ordinal variable, where the observation methods allow to construct scales ranges from lowest to highest, according to the degree of expression [24-27].

To determine the sexual dimorphism are useful univariate nonparametric tests such as Pearson chi-square to measure the discrepancy between observed and a theoretical distribution (goodness of fit), indicating the extent to which differences between the two, if any, are due to chance in the contrast of the assumptions made in this case there is sexual dimorphism, or Mann-Whitney test, applied to two independent samples to test the two-sample heterogeneity ordinal under the null hypothesis that the distributions of departure of both distributions is the same, meaning that there is sexual dimorphism in the sample. For both tests, we adopt a  $p < 0.05$  in a normal distribution of the sample to reject the null hypothesis in terms of statistical significance [63].

## 4. Dental dimensions

Among the object of study of dental anthropology in his interest in recording, study, analyze, explain and understand the information provided by the human dentition, such as anatomical variations, developmental, pathological, cultural and therapeutic consideration with living conditions, culture, food and adaptation processes of the past and present human populations, are important the odontoscopia, the odontometry, the oral paleopathology, and modifications of the teeth. Based on this concept extensively reviewed in the literature, the odontometry or registration of dental dimensions should be studied from an interdisciplinary perspective (biology, anthropology, dentistry, paleopathology, archeology, forensics) since the teeth are the precise means to recognize individuals whose death makes it difficult to distinguish by other processes, which are part of the reconstruction of the osteobiography or odontobiography individual and general, contributing just as in estimating biological populations to clarify past its history, origin, training, contacts and movements of the past and present human groups [2,5,6,64].

Sex determination from dental measures has been one of the least developed in physical anthropology. Sex is central to this research and to help determine the taxonomic value of the traits examined [7]. The odontometry and obtaining coronal and root action of the teeth are used in different ways, depending on the interest of the study. In the dental context dimensions of the teeth are useful for the prediction of space for orthodontic treatment and orthodontics. In the anthropological context are used in comparative evolutionary studies and for establishing phylogenetic relationships among species of hominids and disappeared modern humans and to determine biological distances between populations, the same way they are used to diagnose the sex of individuals and complete paleo-demographic information of past populations. Finally, in the forensic context are useful for determining the sex of an individual in the process of identification [6,11].

Worldwide research on this topic has sheltered many of the current populations and a number of past populations, which has contributed to the elucidation of the human evolutionary processes, the population distribution in the continents of Africa, Europe and Asia, the settlement of the Americas, and the formation of population clusters by means of the dimensions of the teeth [28,29,31,40].

Since the simplification of the morphology and tooth size reduction has been the trend in the evolution of hominids, A. Zoubov -cited by J. V. Rodriguez [6]- groups the different hominid groups according to tooth size and explains them in ten points.

1. The most close to the taxonomic position Pliocene hominid are African Lothagam and Lukeino remains (6.5 and 5.5 million years), which are located in dental traits intermediate between apes and early hominids, very similar to happens to the *Ardipithecus ramidus* (4.4 million years ago) found in Ethiopia, whose small teeth resemble the characteristics of a chimpanzee with australopithecine cranial traits. Subsequently, the *Australopithecus afarensis* (3.5 million years ago) and *Homo habilis* (2.3 to 1.7 million years) are characterized by a higher proportion of their teeth humanoid (correlation of size between the anterior and posterior). For its part, the anterior teeth of *A. africanus* (3 and 2.5 million years) and *A. robustus* and *A. boisei* (2.5 to 1.5 million years) are proportionally small compared to the premolars and molars are very large. All australopithecines are characterized by molarización of the premolars and third molars large, larger than the second molars and these in turn larger than the first molars ( $M3 > M2 > M1$  as meso-distal diameter).
2. Middle Pleistocene hominids such as *Homo erectus*, are characterized by a dental size smaller than their ancestors australopithecines but larger than in *Homo sapiens*. Compared to all *Homo habilis* had smaller teeth, excluding the lateral incisor and canine. According to the meso-distal diameter ratio had already humanoid  $M1 > M2 > M3$  and harmonic proportion between the anterior and posterior teeth. Zoubov states, according to the variation of some dental traits, from that moment begin to set the division of the populations of the genus *Homo* into two branches: the western forms including African and European and eastern with Asian.
3. The remains known as pre-Neanderthals (450,000 and 250,000 years), labeled as archaic *Homo sapiens* or Neanderthal associated with late *erectus* or archaic, does not allow a clear division of dental dimensions and morphology, except for the presence of a bridge of enamel that connects the protoconid and metaconid of the lower molars, characteristic of European Neanderthals, indicating a relationship of genetic continuity.
4. Regarding the Neanderthals (200,000 and 35,000 years), two dental variants have been observed, a macrodonte (Krapina and Shanidar) and another microdonte (Hortus), which anyway, compared to other developmental stages, canines, premolars and molars show reduced while the incisors show an increase in size. For Asian and European Neanderthals is characteristic shovel-shape of the incisors.

5. In the case of modern humans (*neanthropus*), tooth size is reduced relative to the Middle Pleistocene hominids, although with differential gradients in various regions of the world, beginning the ethnic variation over the geographic distribution of this condition. This condition increases after the Late Pleistocene, about 100,000 years ago.
6. Dental size reduction during the Late Pleistocene compared dental size between modern populations, and between the latter and the prehistoric to observe from the perspective of differences in body size, including sexual dimorphism between each taxonomic group, more evident in the canine teeth.
7. This reduction in the Upper Pleistocene dental started long before the present changes in the composition of the diet, but can be correlated with the adoption of new techniques in their preparation and use of earth ovens for cooking food, it that reduced masticatory pressure and relaxed the selection forces that remained stable during the Pleistocene. The resulting tooth reduction was the product of that C. Brace called probable mutational effect.
8. At the end of the Pleistocene the adoption of ceramics further relaxed selection forces, the beneficiaries of reduced dental system at a rate of 1% per 1,000 years. While during the Pleistocene the rate of reduction was 1% for 100,000 years, after this period was 1% for 1,000 years.
9. The maximum tooth reduction is presented in a northern strip that extends from the western to the eastern extremity. The present inhabitants of that region are the descendants of the first people to cook food.
10. To the south of the areas with oldest non-use of the teeth in the preparation of food, tooth size increases in proportion to the recent culinary skills. *Homo sapiens* within the lower tooth reduction are observed among the Australian Aborigines, although used as ovens on the ground for the arrival of Europeans, did not use pottery for cooking food.

First described by A. Zoubov, J. V. Rodriguez [6] argues that although tooth reduction (downsizing and streamlining of structures) was an evolutionary trend of the dental system of man, should not be understood as the loss of features, as Carabelli's tubercle and styloid formations were acquisitions undertaken in the late stages of the sapientization, as explained by the reduction theory proposed by mutational effect. Added to this, I. Shmalgausen proposes a theory about the accumulation of mutations, which holds that the simplification of the organs is a result of the uncontrolled accumulation of mutations that loosen the correlated systems during ontogenesis, in the case of the teeth, reducing the rate of growth individual body could have generated the reduction of its size, sexual dimorphism even disappearing. Other factors such as genetic isolation could produce increased tooth size, while the hybridization or miscegenation, however, could have generated reduction and simplification of the structures.

From the population point of view, the comparison of dental dimensions of different ethnic groups and those associated with the four major complexes (Australoid, Caucasoid, Mongoloid and Negroid) highlights the specificity of dental size of different populations,

thus Australoids are macrodonts. Observed differences between Caucasoid and Negroid are not significant, especially labiolingual diameter of almost all teeth. The differences are more noticeable in mesiodistal diameter, particularly upper lateral incisor, premolar, second molar, mandibular canine, first premolar, first and second lower molar. The largest absolute differences are observed in the mesodistal diameter of the incisors, especially the lateral incisor, and premolars when Caucasoid and Mongoloid are compared. The Negroid reflect minor differences compared with the three major geographic and racial groups. The differences between Mongoloid and Negroid are almost nonexistent, excluding second molars [6].

#### 4.1. Metric dental traits

The study of dental dimensions of the teeth has shown that these have a high heritability within populations worldwide. The same has been demonstrated in the study of identical twins, which is why the diameters of the crowns of the teeth have been classified as "continuous variations" whose adaptive capacity is largely related to the functions of the stomatognathic system (chewing) and detached so relative influence of the environment [56, 65, 66]. Odontometric measures of the crowns of the teeth or metric dental crown traits more under study are meso-distal diameter, defined as the distance between the contact points interproximal mesial and distal and bucco-lingual diameter (lingual for lower teeth), defined as the distance between the highest convexities of the buccal and palatal (lingual) [67], because these dimensions are not affected by the wear caused by attrition during chewing or the abrasive properties of some foods [6].

For the measurements of the diameters methods used are from C. Moorrees et al [68] for meso-distal diameters (distance between the surfaces of contour mesial and distal reference plane having as the occlusal surface), in which the gauge is placed parallel or vertical to the surface occlusal so that the tips locate the areas of the mesial interproximal contact points and distal and from J. Kieser et al [69] for bucco-lingual diameters (distance between the points of greatest convex of the buccal and lingual taking as a reference plane to the occlusal surface), in which the gauge is placed parallel or vertical to the occlusal surface so that the planes of the ends locate the areas of greatest convexity of the buccal and lingual surfaces.

For individual analysis, with meso-distal dimensions and vestibule-lingual, can be calculated means as the coronal module (sum of the diameters meso-distal and bucco-lingual divided by two), the coronal index (bucco-lingual diameter multiplied by 100 and divided by the meso-distal diameter), the index of robustness of each tooth (crown area corresponds to the product of the diameters meso-distal and bucco-lingual) and the index of robustness of the dentition (sum of the indices of strength of all teeth divided by the number of types of teeth taken into account). Similarly, all these measures and indices obtained can be averaged and be applied to population analysis (frequencies, sexual dimorphism, bilateral symmetry, correspondence between metric traits within the same kind of teeth and biological distances) [12].

## 4.2. Sexual dimorphism and bilateral symmetry

With respect to sexual dimorphism, different authors claim that the size of the teeth is genetically determined in about 90% (64% in mesodistal diameter), so they are not affected by nutritional status or the environment. In contemporary populations has been shown that the average dimorphism with respect to meso-distal diameter is 3.1%, being canine the most dimorphic tooth. Also has been shown, from the point of view of the correspondence between the teeth of the same class that distal teeth (lateral incisor, second premolar and second molar) are the most variable [6].

The study of dental dimensions has been used to understand sexual dimorphism in the socio-ecological and phylogenetic primate evolution. Sexual dimorphism is defined as an intraspecific difference between men and women, which can be studied from the somatotype of the individual, the size and dental morphology, and correlated with patterns of intrasexual competition. During evolution, there have been ontogenetic mechanisms that cause morphological differences between males and females during primate evolution. The ontogenetic changes in these processes lead to the existence of sexual dimorphism associated with the size and evolutionary response to various factors including territoriality, competition and the distribution of resources. However, in modern humans, the restriction of many of these factors has caused the sexual dimorphism of tooth size has almost disappeared, except perhaps in the canine teeth [70].

The meso-distal and bucco-lingual teeth diameters from 100 Americans and 100 Caucasian Americans of African descent, stating that sexual dimorphism is 1.2% of the sample, while the differences between the two ethnic groups was 4.9%. The results allowed concluding that there were no significant differences between these two variables and it is difficult to establish lines of analysis given the large intra-group variations. S. Paulino et al [71] studied the dental dimensions in 153 models (115 women and 38 men) and found that there is a significant difference in the meso-distal diameter between women and men, being higher in the latter. M. Ates et al [72] determined the meso-distal and bucco-lingual diameters in a sample of 100 Turks (50 men and 50 women) and concluded that there is no sexual dimorphism in the observed sample. I. Suazo et al [73] reported that in all the permanent teeth of 150 Chilean individuals (67 men and 83 women), meso-distal and bucco-lingual diameters are higher in men, but these differences are not significant and therefore are not can consider the existence of sexual dimorphism. Astete et al [74] compared two samples of Spanish and Chilean concluding that the diameters from meso-distal and vestibulo-lingual, has a greater sexual dimorphism in Spanish than Chileans, however this difference was not statistically significant. L. Castillo et al [75] in a Colombian sample of mixed Caucasians, concluded that the meso-distal and bucco-lingual diameters are not sexually dimorphic, which was associated with the disappearance of the selective pressure of the dimorphic characteristic strength between men and women. Also these authors observed no differences in bilateral symmetry with respect to sex in the diameters of the right and left teeth in the same class, which highlights the degree of conservation of this property and its clinical significance for dental diagnosis and treatment (Table 3).



Teeth	Gender	Meso-distal diameters			Bucco-lingual diameters		
		Promedio	Standard deviation	Sexual dimorphism ( $p<0.05$ ]	Promedio	Standard deviation	Sexual dimorphism ( $p<0.05$ ]
UI1	Mujeres	8.368	.4619	.037	7.264	.6584	.282
	Hombres	8.653	.6211		7.068	.7690	
UI2	Mujeres	6.879	.5750	.925	6.436	.7607	.505
	Hombres	6.892	.5749		6.313	.7133	
UC	Mujeres	7.929	.7164	.897	7.754	1.0401	.804
	Hombres	7.908	.5753		7.692	.9556	
UP1	Mujeres	7.193	.7707	.779	9.679	.6641	.647
	Hombres	7.257	.7808		9.608	.5810	
UP2	Mujeres	6.900	.6128	.545	9.629	.6259	.998
	Hombres	7.003	.7198		9.629	.5229	
UM1	Mujeres	10.189	.5500	.902	11.246	.6149	.493
	Hombres	10.158	1.2567		11.335	.6479	
UI1	Mujeres	8.386	.7204	.176	7.318	.7087	.208
	Hombres	8.597	.5380		7.074	.8140	
UI2	Mujeres	6.911	.6057	.792	6.496	.7167	.314
	Hombres	6.871	.6004		6.311	.7479	
UC	Mujeres	8.036	.7004	.425	7.818	.9495	.316
	Hombres	7.916	.5144		7.603	.7786	
UP1	Mujeres	7.225	.4956	.822	9.661	.6957	.958
	Hombres	7.197	.4857		9.653	.5559	
UP2	Mujeres	6.829	.5241	.681	9.646	.7010	.721
	Hombres	6.887	.5960		9.700	.5110	
UM1	Mujeres	10.179	.5159	.112	11.164	.6510	.097
	Hombres	10.418	.6505		11.439	.6559	
LI1	Mujeres	5.225	.5001	.606	5.836	.5086	.191
	Hombres	5.284	.4265		6.000	.4926	
LI2	Mujeres	5.92	.576	.935	6.293	.6475	.520
	Hombres	5.91	.442		6.197	.5494	
LC	Mujeres	6.921	.5833	.617	7.264	.5958	.436
	Hombres	6.987	.4743		7.142	.6467	
LP1	Mujeres	7.007	.5537	.054	7.929	.6604	.385
	Hombres	7.287	.5855		8.063	.5842	
LP2	Mujeres	6.971	.6121	.078	11.404	15.2266	.326
	Hombres	7.237	.5838		8.521	.5822	
LM1	Mujeres	10.789	1.1808	.245	10.421	.6008	.593
	Hombres	11.103	.9857		10.526	.8946	
LI1	Mujeres	5.304	.3805	.850	5.936	.5599	.637

Teeth	Gender	Meso-distal diameters			Bucco-lingual diameters		
		Promedio	Standard deviation	Sexual dimorphism ( $p<0.05$ ]	Promedio	Standard deviation	Sexual dimorphism ( $p<0.05$ ]
	Hombres	5.324	.4553		5.997	.4949	
LI2	Mujeres	5.936	.4621	.520	6.236	.5342	.306
	Hombres	5.858	.4984		6.118	.3896	
LC	Mujeres	6.829	.6176	.571	6.943	.7781	.619
	Hombres	6.908	.5138		7.034	.6988	
LP1	Mujeres	7.218	.4423	.808	7.800	.6176	.085
	Hombres	7.245	.4409		8.056	.5613	
LP2	Mujeres	7.114	.6340	.480	8.282	.7434	.182
	Hombres	7.213	.4955		8.503	.5838	
LM1	Mujeres	11.029	.6446	.048	10.354	.6420	.033
	Hombres	11.332	.5733		10.705	.6505	

**Table 3.** Sexual dimorphism of the metric dental traits al the comtemporary colombian Caucasian mestizo population

### 4.3. Statistical analysis of sexual dimorphism

Since dental metric traits analyzed according to their measure and subsequently grouped into averages or means and standard deviations are obtained at the time to categorize the variables for the descriptive statistical analysis, each degree of expression of metric traits constitutes a quantitative ratio variable, where the observation methods for determining the measure in terms of metric units [39].

To determine the sexual dimorphism are useful parametric tests such as Student's t test to prove a hypothesis, which in this case means that if there is sexual dimorphism. It comes from a probability distribution that arises from the problem of estimating the mean of a normally distributed population when the sample size is small, considering that the observations must be independent and must be performed on normally distributed population universes whose variances groups should be homogeneous, which is not true for meso-distal diameters and vestibule-lingual, so it is necessary to previously apply the Kolmogorov-Smirnov test to determine normality and Levene to determine equality of variances . For this test, we adopt a  $p < 0.05$  in a normal distribution of the sample to reject the null hypothesis in terms of statistical significance [63].

### Author details

Freddy Moreno-Gómez

*Dental School at the Universidad del Valle Cali, Colombia*

*Department of Medical Sciences at the Pontificia Universidad Javeriana Cali, Colombia*

*Pontificia Universidad Javeriana Cali, Colombia*

## 5. References

- [1] Rodríguez JV. Introducción a la antropología dental. Cuadernos de antropología. 1989; 19:1-41.
- [2] Scott GC, Turner II CG. The anthropology of modern human teeth: dental morphology and its variation in recent human populations. First published. London: Cambridge University Press; 1997.
- [3] Moreno F, Moreno SM, Díaz CA, Bustos EA, Rodríguez JV. Prevalencia y variabilidad de ocho rasgos morfológicos dentales en jóvenes de tres colegios de Cali, 2002. Colomb Med 2004; 35 (3-Supl 1):16-23.
- [4] Hochrein MJ. Buried crime scene evidence: the application of forensic geotaphonomy in forensic archaeology. In forensic dentistry, Stimson PG, Mertz CA, editors. First edition. London: CRC Press; 1997.
- [5] Scott GC, Turner II CG. Dental anthropology. Ann Rev Anthropol 1998; 17: 99-126.
- [6] Rodríguez JV. Dientes y diversidad humana: avances de la antropología dental. Primera edición. Santa Fe de Bogotá: Universidad Nacional de Colombia; 2003.
- [7] Rodríguez CD. Antropología dental prehispánica: variación y distancias biológicas en la población enterrada en el cementerio prehispánico de Obando, Valle del Cauca, Colombia entre los siglos VIII y XIII d.C. Syllaba Press. Miami. 2003.
- [8] Rodríguez CD. La antropología dental y su importancia en el estudio de los grupos humanos prehispánicos. Revista de Antropología Experimental 2004; 4.
- [9] Rodríguez CD. La antropología dental y su importancia en el estudio de los grupos humanos. Rev Fac Odont Univ Ant 2005; 16(1 y 2): 52-59.
- [10] Marín L, Moreno F. Odontología forense: identificación odontológica, reporte de casos. Rev Estomat 2003; 11(2):41-49.
- [11] Rodríguez JV. La antropología forense en la identificación humana. Universidad Nacional de Colombia. Bogotá. 2004.
- [12] Hillson S. Dental anthropology. First edition. London: Cambridge University Press; 1996.
- [13] Alt KW, Rosing FW, Teschler-Nicola M. Dental anthropology: fundamentals, limits, and prospects. New York: Springer-Verlag; 1998.
- [14] Mayhall JT. Dental morphology: techniques and strategies. In Biological anthropology of the human skeleton, Katzenberg MA, Saunders SR (Editors). Wiley-Liss, New York. 2000. p. 103-134.
- [15] Zoubov AA. La antropología dental y la práctica forense. Maguaré 1998; 13:243-252.
- [16] Turner II CG, Nichol CR, Scott GR. Scoring procedures for key morphological traits of the permanent dentition: the Arizona State University dental anthropology system. In Nelly MA, Larsen CS (editors). Advances in dental anthropology. New York: Wiley-Liss Inc; 1991. p. 13-31.
- [17] Hanihara, K. Mongoloid dental complex in the deciduous dentition. J Anthropol Soc Nippon 1966; 74: 9-20.
- [18] Sciuilli PW. Evolution of Dentition in Prehistoric Ohio Valley Native Americans: II. Morphology of the Deciduous Dentition. Am J Phys Anthropol 1998; 106:189-205.
- [19] Grine FE. Anthropological Aspects of the Deciduous Teeth of African Blacks. En Singer L y Lundy JK (Eds) Variation, Culture and Evolution in African Populations. Johannesburg: Witwatersrand University Press. 1986. p 47-83.

- [20] Nichol CR, Turner II CG. Intra and inter-observer concordance in classifying dental morphology. *Am J Phys Anthropol* 1986; 69:299-315.
- [21] Jordan RE, Abrams L, Kraus BS. *Kraus' dental anatomy and occlusion*. St. Louis: Mosby; 1992
- [22] Woelfel JB, Scheid RC. *Dental anatomy: its relevance to dentistry*, 5th ed. Baltimore: Lippincott Williams and Wilkins; 1997.
- [23] Ash MM, Nelson SJ. *Wheeler's dental anatomy, physiology, and occlusion*. 9th ed. Philadelphia: W.B. Saunders; 2009.
- [24] Moreno SM, Moreno F. Eight Non-Metric dental traits in alive racially mixed population from Cali, Colombia. *Inter J Dental Anthropol* 2005; 6:14-25.
- [25] Aguirre L, Castillo D, Solarte D, Moreno F. Frequency and Variability of five non-metric dental crown traits in the primary and permanent dentitions of a racially mixed population from Cali, Colombia. *Dental Anthropology* 2006; 19(2): 39-47.
- [26] Rocha L, Rivas H, Moreno F. Frecuencia y variabilidad de la morfología dental en niños afro-colombianos de una institución educativa de Puerto Tejada, Cauca, Colombia. *Colomb Med* 2007; 38: 210-221.
- [27] Aragón N, Bastidas C, Bedón LK, Duque P, Sánchez M, Rivera S, Triana F, Noel Bedoya N, Moreno F. Rasgos morfológicos dentales coronales en dentición temporal y permanente: Distancia biológica entre tres grupos indígenas del Amazonas Colombiano. *Revista Odontológica Mexicana* 2008; 12(1):13-28.
- [28] Hanihara T. Dental and cranial affinities among populations of East Asia and the Pacific. *Am J Phys Anthropol* 1992; 88:163-182.
- [29] Turner II CG. Advances in the dental search for native American origins. *Acta Anthropogen* 1984; 8:23-78.
- [30] Turner II CG. Late pleistocene and Holocene population history of East Asia based on dental variation. *Am J Phys Anthropol* 1987; 73:305-321.
- [31] Turner II CG. Major features of sudadonty and sinodonty, including suggestions about East Asian microevolution, population history and late Pleistocene relationships with Australian aboriginals. *Am J Phys Anthropol* 1990; 82:295-317.
- [32] Butler PM. Ontogenetic aspects of dental evolution. *Int J Dev Biol* 1995; 39: 25-34.
- [33] Simons EL, Plavcan JM, Fleagle JG. Canine sexual dimorphism in Egyptian Eocene anthropoid primates: *Catopithecus* and *Proteopithecus*. *Proc Natl Acad Sci* 1999; 96:2559-62.
- [34] Alba DM, Moyá-Solá S, Köhler M. Canine reduction in the Miocene hominoid *Oreopithecus bambolii*: behavioural and evolutionary implications *Journal of Human Evolution* 2001; 40:1-16.
- [35] Plavcan JM, van Schaik CP, Kappeler PM. Competition, coalitions and canine size in primates. *Journal of human evolution* 1995; 28:245-276.
- [36] Goyes J, Guerrero L, Narváez N, Moreno F. Rasgos morfológicos dentales coronarios de caninos temporales y permanentes en un grupo de mestizos de Cali, Colombia. *Revista Colombiana de Investigación en Odontología* 2011; 2(5):1-13.
- [37] Irish JD, Morris DH. Technical Note: Canine Mesial Ridge (Bushman Canine) Dental Trait Definition. *American Journal of Physical Anthropology* 1996; 99:357-9.
- [38] Nagai A, Kanazawa E. Morphological Variations of the Lower Premolars in Asian and Pacific Populations. In *Dental Morphology '98*. Proceedings of the 11th International Symposium on Dental Morphology, Mayhall JT, Heikkinen T (Editors) Oulu, Finlandia; 1998. p.192-205.

- [39] Girón G, Gómez P, Morales L, León M, Moreno F. Rasgos Morfológicos y Métricos Dentales Coronales de Premolares Superiores e Inferiores en Escolares de Tres instituciones Educativas de Cali, Colombia. *Int J Morphol* 2009; 27(3):913-925.
- [40] Hanihara K. Racial characteristics in the dentition. *J Anthropol Soc Japan* 1967; 46: 923-926.
- [41] Hanihara K. Mongoloid dental complex in the permanent dentition. *Proceedings of the VIIIth International Symposium of Anthropological and Ethnological Sciences*. Tokyo and Kyoto: Science Council of Japan; September 3-10, 1968. p. 298-300.
- [42] Snow SR. Esthetic smile analysis of maxillary anterior tooth width: the golden percentage. *Journal of Esthetic Dentistry* 1999; 11(4): 177-184.
- [43] Seluk LW, Brodbelt RHW, Walkera GF. Biometric comparison of face shape with denture tooth form. *Journal of Oral Rehabilitation* 1987; 14: 139-145
- [44] Crespi R, Grossi SG. The emergence margin in prosthetic reconstruction of periodontally involved teeth. *The International Journal of Periodontics & Restorative Dentistry* 1993; 13(4): 349-360.
- [45] Sellen P, Jagger D, Harrison A. The correlation between selected factors which influence dental aesthetics. *Prim Dent Care* 1998; 5(2):55-60.
- [46] Ahmad I. Anterior dental aesthetics: Facial perspective. *British Dental Journal* 2005; 199(1):15-21.
- [47] Anderson KM, Behrents RG, McKinney T, Buschang PH. Tooth shape preferences in an esthetic smile. *Am J Orthod Dentofacial Orthop* 2005; 128:458-65.
- [48] Ibrahimagi L, V. Jerolimov V, Celebic A, Carek V, Baucic I, Knezovic-Zlaticaric D. Face and Tooth Form, *Coll Antropol* 2001; 25 (2): 619-626.
- [49] Waliszewski M. Restoring dentate appearance: A literature review for modern complete denture esthetics. *J Prosthet Dent* 2005; 93:386-94.
- [50] Berksun S, Hasanreisoglu U, Gökdeniz B. Computer-based evaluation of gender identification and morphologic classification of tooth face and arch forms. *J Prosthet Dent* 2002; 88(6):578-84.
- [51] Wolfart S, Menzel H, Kern M. Inability to relate tooth forms to face shape and gender. *Eur J Oral Sci* 2004; 112(6):471-6
- [52] Acosta D, Porras A, Moreno F. Relación entre forma del contorno facial, arcos dentarios e incisivos centrales superiores en estudiantes universitarios de la ciudad de Cali *Rev Estomat* 2011; 19(1):14-19.
- [53] Kinzey WG. Evolution of the Human Canine Tooth. *American Anthropologist* 1971; 73(3): 680-94.
- [54] Schwartz GT, Dean C. Ontogeny of Canine Dimorphism in Extant Hominoids. *Am J Phys Anthropol* 2001; 115:269-83.
- [55] Greenfield LO. Origin of the Human Canine: A New Solution to an Old Enigma. *Yearbook of Physical Anthropology* 1992; 35:153-85.
- [56] van Reenen F, Reid C, Butler P. Morphological studies on human premolar crowns. In *Dental Morphology '98*. *Proceedings of the 11th International Symposium on Dental Morphology*, Mayhall JT, Heikkinen T. (Editors) Oulu, Finlandia; 1998. p.192-205.
- [57] Martínón-Torres M, Bastir M, Bermúdez de Castro JM, Gómez A, Sarmiento S, Muela A, Arsuaga JL. Hominin lower second premolar morphology: evolutionary inferences through geometric morphometric analysis. *J Hum Evol* 2006; 50:523-33.



- [58] Harris EF. Where's the Variation? Variance Components in Tooth Sizes of the Permanent Dentition. *Dental Anthropology* 2003; 16(3):84-94.
- [59] Moreno S, Moreno F. Antropología dental: una herramienta valiosa para fines forenses. *Rev Estomat* 2001; 10(2):29-42.
- [60] Edgar HJH. Prediction of race using characteristics of dental morphology. *J Forensic Sci* 2005; 50(2):1-5.
- [61] Edgar HJH, Lease LR. Correlations between deciduous and permanent tooth morphology in a european american sample. *Am J Phys Anthropol* 2007; 133:726-734.
- [62] Ocampo AM, Sánchez JD, Martínez C, Moreno F. Correlación de diez rasgos morfológicos dentales coronales entre molares deciduos y permanentes en tres grupos étnicos colombianos. *Rev Estomat* 2009; 17(2):7-16.
- [63] Armitage P, Berry G, Matthews JNS. Statistical methods in medical research. John Wiley & Sons: New York; 2002.
- [64] Rodríguez CD, Delgado ME. Dental anthropology: a brief definition. *Int J Dental Anthropol* 2000; 1:2-4.
- [65] Reid C, van Reenen F. Reduction in human premolar crowns. In: *Dental Morphology '98. Proceedings of the 11th International Symposium on Dental Morphology*, Mayhall JT, Heikkinen T. (Editors) Oulu, Finlandia; 1998. p. 85-91.
- [66] Swindler DR, Drusini AG, Cristino C. & Ranzato C. Comparison of molar crown size precontact Easter Islanders with other Pacific groups. In *Dental Morphology '98. Proceedings of the 11th International Symposium on Dental Morphology*, Mayhall JT, Heikkinen T. (Editors) Oulu, Finlandia; 1998. p.63-73.
- [67] Bernabé E, Lagravère MO, Flórez C. Permanent dentition mesio-distal and buccolingual crown diameters in a Peruvian sample. *Inter J Dental Anthropol* 2005; 6:1-13.
- [68] Moorrees CFA, Thomsen SO, Jensen E, Yen PK. Mesiodistal crown diameters of the deciduous and permanent teeth in individuals. *J Dent Res* 1957; 36(1): 39-47.
- [69] Kieser JA, Groeneveld HT, Prestosn CB. An odontometric analysis of the Lengua Indian dentition. *Hum Biol* 1985; 57(4): 611-620.
- [70] Schwartz GT, Miller ER, Gunnell GF. Developmental processes and canine dimorphism in primate evolution. *Journal of Human Evolution* 2005; 48:97-103.
- [71] Paulino S, Paredes-Gallardo V, Gandía-Franco JL, Cibrián-Ortiz de Anda RM. Evolución de las características de las arcadas dentarias en dos grupos de edad. *RCOE* 2005; 10(1):47-54.
- [72] Ates M, Karaman F, Iscan M, Erdem TM. Sexual differences in Turkish dentition. *Legal Medicine* 2006; 8:288-292.
- [73] Suazo IS, Cantín M, López F, Sandoval C, Torres S, Gajardo P, Gajardo M. Dimorfismo Sexual en las Dimensiones Mesiodistales y Bucolinguales de las Piezas Dentarias en Individuos Chilenos. *Int J Morphol* 2008; 26(3):609-614.
- [74] Astete C, Valenzuela J, Suazo I. Sexual Dimorphism in the Tooth Dimensions of Spanish and Chilean peoples. *Int J Odontostomat* 2009; 3(1):47-50.
- [75] Castillo L, Castro A-M, Lerma C, Lozada D, Moreno F. Diámetros meso-distales y vestibulo-linguales dentales de un grupo de mestizos de Cali, Colombia. *Rev Estomat* 2012; 20(1):16-22.