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Morphometric Investigation in the Skulls of Young Adults

A Comparative Study between 19th Century and Modern Italian Samples

Efisio Defraia;[a] Matteo Camporesi;[b] Andrea Marinelli;[c] Isabella Tollaro[d]

ABSTRACT

Objective: To test the hypothesis that there are no differences in the shape of the cranial complex between two samples from the same restricted geographical area and separated by almost 150 years.

Materials and Methods: A group of 35 skulls from the 19th century were selected and compared with a modern sample composed of 43 young adult subjects by means of lateral cephalograms and using a morphometric analysis. The peculiarity of this work is the uniformity of the two samples involving adults coming from the same restricted birthplace and with homogeneity for the orthodontic classification.

Results: Although the time spans are short, significant differences were found between the two samples. Shape changes included maxillary elongation toward the posterior region and a marked change in shape configuration in the mandible's points that shows a posterior rotation of the mandibular body. The global result of this cranial base point's movements symbolizes a tiny tendency toward closure of the cranial base angle.

Conclusions: The hypothesis is rejected. Changes were evident, and environmental influences can be responsible for these changes.

KEY WORDS: Cephalometric analysis, Cranium, Thin-plate spline.

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INTRODUCTION Return to TOC

Malocclusions, caries, hypertension, diabetes, and heart disease are diffuse pathologies in modern populations, although they are uncommon in underdeveloped societies.[1] Facial patterns have close relationships with neuromuscular activities.[2–4] Corruccini and Whitley[5] hypothesized that decreased function of the masticatory system, as a consequence of processed food, should be responsible for inadequate development of the jaws (disuse theory). Lindsten et al[6] observed that many contemporary children chew gum frequently and reasoned that the lack of function of the masticatory system cannot be isolated as a causative factor of the increasing prevalence of malocclusions. On the contrary, mouth breathing as a consequence of an increase in respiratory diseases such as allergy and asthma[7–13] should be considered as a potential important causative factor for this tendency.

Secular trends in occlusal patterns have been described in numerous different ethnic groups, not only between ancient and modern subjects but also in the comparison among cohorts of the past century separated by three decades.[14–19] The growth of the nasomaxillary complex and the mandible is influenced by the functional matrix because they support most of the functional organs.[20] The cranial base comprises several skeletal units and is characterized not only as supporting the brain but also as the connecting element among the brain and functional organs.

Cranial base orientation and flexion derives from differences in natural head posture, evolutionary history, and genetic origin.[21–25] Conventional cephalometric analysis shows several limitations and has resulted in the proposal and implementation of new biometric analyses of landmark data (eg, elliptic Fourier analysis, finite element analysis, tensor and shape coordinate analysis).[26–29] The major advantages of these still-evolving methods include separate evaluation of shape (or of shape change) and size with no need for reference structures or lines and visualization of morphological changes.

Thin-plate spline (TPS) analysis has been applied by Singh et al[30,31] to the description of the cranial base configuration in subjects with structural malocclusions characterized by mandibular protrusion. TPS was also used for the description of the growth features of subjects affected by skeletal Class II malocclusion[32,33] and for the evaluation of therapeutic effects of orthodontic therapy.[34] Moreover, TPS analysis has been used to study the dental arch shape of young adults.[35]

The aim of the present investigation is to evaluate by means of morphometric analysis (TPS analysis) the differences in the shape of the cranial complex between two samples coming from the same restricted geographical area and separated by almost 150 years to investigate the evolutionary trends affecting the craniofacial region. The two samples are composed of (1) a group of adult subjects derived from a contemporary population and (2) a group of adult subjects born at the beginning of the 19th century.

MATERIALS AND METHODS Return to TOC

Sample From the 19th Century

Thirty-five skulls from the 19th century were selected from a sample of 150 skulls from the area of Florence, Italy (16 men and 19 women), now housed at the Museum of Anthropology of the University of Florence. The mean age of the sample was 26 ± 4 years (27 ± 4 years for the men and 25 ± 3 years for the women). They were a group of low social class, and they had not lived in comfortable conditions.

The skulls examined were selected on the basis of the following criteria: (1) no obvious cranial deformity, (2) no missing parts of fractures of the jaw bones or dental arches, (3) presence of the mandible, and (4) presence of sufficient teeth to provide a definite occlusion and mandibular articulation.

One lateral cephalogram was obtained for each skull with the teeth in centric occlusion. On all lateral cephalograms, anatomical structures were traced, and the midline of all contours of bilateral structures was traced to minimize the error due to positioning, differential magnification, and asymmetry.

Contemporary Sample

The contemporary sample was composed of 43 subjects (13 men and 30 women) with a mean age of 20 ± 3 years (20 ± 2 years for the men and 21 ± 3 years for the women) selected from the files of the Department of Orthodontics of the University of Florence, Italy.

The sample was selected using the following criteria:

- adult dentition including the second molars,
- skeletal maturation by morphological evaluation of the cervical vertebrae,[36] and
- absence of previous or current orthodontic treatment.

All subjects were white young adults belonging to the same geographical area (Florence). They were born in this geographical area, and they belonged to a middle social class.

The matched samples were homogenous with regard to sagittal skeletal relationship.[37] The sample from the 19th century was composed of 18 Class I, 9 Class II, and 8 Class III subjects, whereas the contemporary sample was composed of 22 Class I, 11 Class II, and 10 Class III subjects.

Landmarks

The cranial landmarks digitized and employed in this study are described in Figure 1. The definition of these points can be found in the works of Björk,[38] Riolo et al,[39] and Tollaro et al.[40]

Digitization of landmark coordinates from cephalograms was achieved using the appropriate software (Viewbox, version 1.9) and a digitizing tablet (Numonics 2210; Numonics Co, Lansdale, Pa). All cephalograms were digitized by the same operator and redigitized by another operator, and the method error in the landmark identification was calculated.

The standard error deviation for each dimension was calculated from the double determinations using Dahlberg's formula REF. The mean value for the method error was 0.31 ± 0.13 mm. TPS analysis was performed using a digitizing tablet (Numonics 2210; Numonics Co), a digitizing software (Viewbox 3.0; D. Halazonetis, Athens, Greece), and a morphometric software (TPS Regr 1.28; F. J. Rohlf, Ecology and Evolution, SUNY at Stony Brook, New York, NY). A statistical analysis of shape differences was performed by means of permutation tests with 1000 random permutations on Goodall *F* statistics.

RESULTS Return to TOC

TPS analysis allowed graphical evidence of the shape changes between the craniofacial configurations of modern and ancient skulls. The graphical display showed the shape change including maxillary elongation toward the posterior region. (Moreover, the analysis of vectors shows a bodily posterior direction of shape change of the maxillary region.) A marked change in shape configuration in the mandible was observed: condylion showed a forward movement, associated with a forward elongation of the region of the chin (pogonion and menton). In the cranial base, a slight tendency for a reduction in its angulation was present.

DISCUSSION Return to TOC

The TPS analysis method, applied to cephalometric landmark configurations, presents several advantages with respect to previous conventional cephalometrics and morphometric systems:

- the most favorable superimposition of landmarks for the analysis of shape changes in complex skeletal configurations without the use of any conventional reference line;
- an explanatory visualization of the deformations using transformation grids;
- the decay of generalized modifications into more specific, local changes; and
- the possibility of statistical evaluation of the shape changes.

TPS analysis has been used to describe shape differences in a variety of craniofacial structures in children with malocclusions or dysmorphogenetic syndromes when compared with normal subjects.[30,41]

TPS analysis demonstrated significantly different shape changes in the craniofacial configuration between the modern young adult group and the sample of skulls from the 19th century. The peculiarity of this work is the uniformity of the two samples, which included young adults originating from the same birthplace as well as homogeneity in terms of orthodontic classification on the basis of skeletal relationships.

Cranial Base

Previous works have demonstrated that the cranial base angle is similar within the same population over a long time,[42,43] but it varies among different populations.[42,44] For instance, Anderson and Popovich[44] and Argyropoulos et al[42] have found a remarkable similarity in the cranial base angle between ancient Greek skulls (1800–1200 BC) and present-day Greek individuals. They suggested that the cranial base angle indicates a genetic homogeneity.

In another study, Kuroe et al[4] found that there are significant differences between the cranial base angle of the European and Asian samples, while a considerable similarity was found between the European and African samples. These authors conclude that their results are insufficient to assert that the population difference or similarity of the cranial base angle in this study reflects the degree of genetic homogeneity of the samples.

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Our results that derive from the implementation of a morphometric approach versus a classical cephalometric approach are in accordance with those of Ingervall et al,[45] who have compared the differences in two samples over a period of 160 years. Ingervall et al[45] examined cranial base differences between 19th-century crania and a modern group. The modern group had a more acute saddle angle, and the study has found some skeletal differences that occurred over comparatively short time spans.

The principal differences between the two groups are graphically displayed in Figure 2. The analysis of the cranial base shows differences that demonstrate an acute cranial base angle with a posterior superior remodeling of the tuberculum sellae in the more modern sample when compared with the more ancient one.

In the global evaluation of the differences between the two samples, the differences in the cranial base are smaller with respect to those detectable in the facial skeleton. These results confirm that the cranium-basal complex is a stable anatomic structure within the head.

Facial Skeleton

According to Enlow and Hans,[20] the cranial base must be considered the bridge between the neurocranium and facial regions, the support on which the face is constructed, so that variations in the cranial base are associated with related modifications in facial shape. The results of the current investigation show how the modifications of the cranial base are associated with between-group differences in maxillary and mandibular shape. Thus, the maxillary complex revealed a tendency to relocate in a posterior direction, with an elongation toward the pterigomaxillary region. The mandibular modifications are easily discernible in the comparison between the two samples. These significant differences are mainly due to a positional change rather than dimensional changes. The condyle appears located in a more anterior position, along with an anterior relocation of the chin in contemporary young adults. The combination of these changes in maxillary and mandibular structures suggests a trend toward mandibular prognathism in more modern populations.

The interpretation of these results can be only tempting, while the comparison of the present outcomes with those of other studies is complicated, particularly by the specific method of morphometric analysis applied here. However, the findings indicate that the modern group exhibited a backward displacement of the maxilla. This modification might be related to an airway space reduction following an increase in the prevalence of atopic diseases (asthma, allergic rhinitis, and atopic dermatitis) in the past decades, especially in developed countries. The so-called hominization process[46] is probably not involved because of the short time spans.

Certainly, the other factors that could have determined the differences in the two samples are the following:

- the influence of the same dietary consistency with effects on both muscle function and attrition,
- the possible effects of evolution together with dietary effects,
- the possible hybridization effects, and
- the differences in social class levels between the two groups with consequences on lifestyle, diet, and muscular stress.

CONCLUSIONS Return to TOC

- The more contemporary sample shows a more acute cranial base flexion and a tendency to a more retruded maxilla and more protruded mandible.
- These differences may be justified (1) by different environmental influences (greater allergens presences), (2) by changes in dietary consistency with effects on both muscle function and attrition, and (3) by hybridization effects (the result of increased rates of breeding leading to increased variation within populations).

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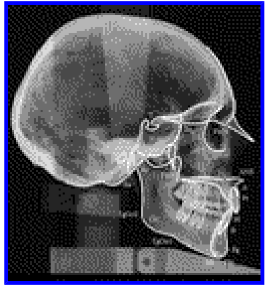

Click on thumbnail for full-sized image.

Figure 1. Tracing showing the cranial landmarks digitized and employed in this study. The definition of these landmarks can be found in Björk,[38] Riolo et al,[39] and Tollaro et al.[40]

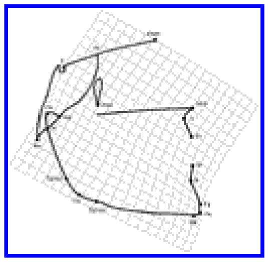

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Figure 2. Thin-plate spline graphical display for the two groups (predecessor vs modern)

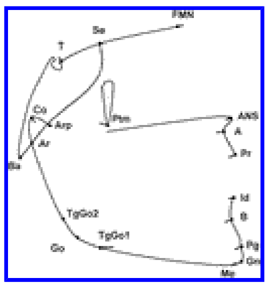

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Figure 3. Vector graphical display (magnification 3×)

[a] Professor, Department of Orthodontics, University of Florence, Florence, Italy

[b] Postdoctorate, Department of Orthodontics, University of Florence, Florence, Italy

[c] Research Associate, Department of Orthodontics, University of Florence, Florence, Italy

[d] Professor and Department Chair, Department of Orthodontics, University of Florence, Florence, Italy

Corresponding author: Dr Andrea Marinelli, Department of Orthodontics, University of Florence, Via del Ponte di Mezzo 46-48, Florence, Italy 50127 (E-mail: a_marinelli@yahoo.com)
