Annals of Anatomy xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Annals of Anatomy

journal homepage: www.elsevier.de/aanat

Differences in skeletal components of temporomandibular joint of an early medieval and contemporary Croatian population obtained by different methods

Josip Kranjcic[a,*], Mario Slaus[b], Sanja Persic[c], Marin Vodanovic[d], Denis Vojvodic[a,e]

[a] Department of Fixed Prosthodontics, School of Dental Medicine, University of Zagreb, Gunduliceva 5, 10000 Zagreb, Croatia
[b] Anthropological Centre, Croatian Academy of Sciences and Arts, Ante Kovacica 5, 10000 Zagreb, Croatia
[c] Department of Removable Prosthodontics, School of Dental Medicine, University of Zagreb, Gunduliceva 5, 10000 Zagreb, Croatia
[d] Department of Dental Anthropology, School of Dental Medicine, University of Zagreb, Gunduliceva 5, 10000 Zagreb, Croatia
[e] Department of Prosthodontics, Clinical Hospital "Dubrava", Av. Gojka Suska 6, 10000 Zagreb, Croatia

ARTICLE INFO

Article history:
Received 11 December 2014
Received in revised form 11 March 2015
Accepted 12 March 2015
Available online xxx

Keywords:
Temporomandibular joint
Articular eminence inclination
Medieval human

ABSTRACT

The temporomandibular joint (TMJ) is one of the most complex joints in the human body. The anatomical configuration of the TMJ allows for a large range of mandibular movements as well as transmission of masticatory forces and loads to the skull base. The measurements of the TMJ's anatomical structures and their interpretations contribute to the understanding of how pathological changes, tooth loss, and the type of diet (changing throughout human history) can affect biomechanical conditions of the masticatory system and the TMJ. The human TMJ and its constituent parts are still the subject of extensive investigation and comparisons of measurement methods are being made in order to determine the most precise and suitable measurement methods. The aim of this study has been to examine the morphology of skeletal components of TMJ of an early medieval population (EMP) in Croatia and to compare measured values with TMJ values of the contemporary Croatian population (CP) using various methods of measurement.

The study was performed on 30 EMP specimens – human dry skulls, aged from 18 to 55 years, and 30 CP human dry skulls, aged from 18 to 65 years. Only fully preserved specimens (in measured areas) were included. The articular eminence (AE) inclination was measured in relation to the Frankfurt horizontal using two methods. Also, the AE height (glenoid fossa depth) and the length of the curved line – highest to the lowest point of the AE were measured. Measurements were performed on lateral skull photographs, panoramic radiographs and lateral cephalograms using VistaMetrix software on skull images. The results were statistically analyzed using SPSS statistical software.

No statistically significant differences were obtained for AE parameters between the EMP and CP populations independent of age and gender. However, statistically significant ($p < 0.05$) differences were revealed when comparing results of three different measuring methods. It could not be determined which of the used measurement methods is the most accurate due to the different results obtained as well as the presence of possible shortcomings and limitations of the various methods (measuring points are difficult to determine and/or they are not clearly observed in the investigated images to be precisely marked and measured; distortion and magnification of structures on radiographic images are present). Therefore, due to the limitations of this study, the obtained results could serve only as orienting information.

1. Introduction

The temporomandibular joints (TMJ), joined by a single mandibular bone, play an essential role in the functioning of the masticatory system. TMJ, as a part of the basicranium, is one of the most complex joints of the human body and its morphology allows a large range of mandibular movements (Curtis, 2011; Kranjcic et al., 2012). Mechanical loading (masticatory forces) as the result of masticatory function is partly transferred through the TMJ to the cranial base and so possibly affects skeletal TMJ morphology

Abbreviations: TMJ, temporomandibular joint; AE, articular eminence; FRT, fossa roof-eminence top; BFL, best fit line; EMP, early medieval population; CP, contemporary population.

* Corresponding author at: School of Dental Medicine, University of Zagreb, Department of Prosthodontics at Clinical Hospital "Dubrava", Av. Gojka Suska 6, 10000 Zagreb, Croatia. Tel.: +385 1 290 3205; fax: +385 1 2864 248.
E-mail addresses: kranjcic@sfzg.hr (J. Kranjcic), mario.slaus@zg.htnet.hr (M. Slaus), persic@sfzg.hr (S. Persic), vodanovic@sfzg.hr (M. Vodanovic), vojvodic@sfzg.hr (D. Vojvodic).

http://dx.doi.org/10.1016/j.aanat.2015.03.004
0940-9602/

(Tanaka and Koolstra, 2008). Skeletal components of the joint are the mandibular condyle and articular eminence (AE) with the fossa glenoidalis of the temporal bone (Fanghänel and Gedrange, 2007). The AE is that part of the temporal fossa over which the condyle-disk complex slides during the various mandibular movements (Katsavrias, 2002). The AE is made up of thick and dense bone which is suitable for loadbearing, whereas the roof of the fossa glenoidalis is thinner, and therefore structurally not able to tolerate high forces (Okeson, 2007; Alomar et al., 2007; Kranjcic et al., 2012). The articular surfaces are irregularly shaped, highly incongruent and separated by a cartilaginous articular disk. The articular disk is thought to reduce incongruence and increase joint stability by enlarging the contact area between the articular fossa and mandibular condyle (Koolstra, 2002; Alomar et al., 2007).

The anatomical morphology of the skeletal components of the TMJ undergoes remodeling throughout life (Meng et al., 2008). The neonatal temporal portion of the joint is quite rudimentary, with a very shallow fossa and the absence of the AE (Thilander et al., 1976; Nickel et al., 1988; Katsavrias, 2002). Therefore, the first months of life are the only period during which the mandibular movements (forward and lateral) occur without any inferior movement (Katsavrias, 2002). The AE is developed almost entirely postnatally; i.e. AE growth and morphology are affected by function (Demirjian, 1963; Pirttiniemi et al., 1990; Katsavrias, 2002; Kranjcic et al., 2012). Therefore, the congenital absence of the condyle is accompanied by underdevelopment of the AE or even by its absence (Kazanjian, 1939; Katsavrias, 2002). The morphology of the AE is also affected by skull base anatomy and genetics (Pirttiniemi et al., 1990; Katsavrias, 2002). Furthermore, the functional morphology of the TMJ depends on changes in the cranial base during ontogeny and hominoid evolution (Koppe et al., 2007). Other factors such as changes in dentition some of which are associated with aging (tooth loss, attrition, increased function, occlusal status and forces, malocclusion), degenerative osseous changes, age and craniofacial growth, cross-cultural differences (especially between groups with different patterns of tooth use and different types of consumed food), gender, ethnicity, facial growth and facial anatomy can also affect TMJ as well as AE morphology (Hinton, 1983; Ikai et al., 1997; Isberg and Westesson, 1998; Zabarovic et al., 2000; Fukui et al., 2002; Katsavrias, 2002, 2003; Jasinevicius et al., 2006; Koppe et al., 2007; Kranjcic et al., 2012).

For many years, the human TMJ has been the subject of extensive investigation and also controversy as to the joint's form and function as well as the question of whether the joint is load-bearing during function (Richards, 1987). Also, very little is known about the TMJ morphology of Croatian historical populations. Considering the fact that environmental factors can affect TMJ morphology (Hinton, 1983; Koppe et al., 2007), the assumption was made of possible differences in AE morphology between an early medieval (EMP) and contemporary Croatian population (CP). Generally, people in the medieval period were more active physically (which was determined according to the frequency of osteoarthritis), the food was raw and harder (than today), and teeth were often used as a tool (Slaus, 2006). Therefore, a steeper AE inclination should be expected. Kranjcic et al. (2012) measured AE inclination on a small sample of human dry skulls excavated at the archeological site Bijelo Brdo, East Croatia and the results showed that the AE inclination of the investigated medieval population was flatter than that of the recent population. Findings of Vodanovic et al. (2003) revealed that the investigated medieval east Croatian population was intensely agricultural with a high consumption of cereals. Their food was not as hard with much soluble material, and consequently, chewing such food required lower masticatory forces. That could be an explanation for the flatter AE inclination recorded in the East Croatian medieval population. However, data from the above mentioned study do not reflect the whole Croatian population which was not intensely agricultural. People were also engaged in fishing, hunting and gathering (consequently different masticatory forces). Therefore, palatal and occlusal tooth surfaces were characterized by progressive tooth wear (Slaus, 2006). The aim of this study is to examine the morphology of skeletal components of the TMJ (AE inclination, AE height and length of curved line from highest to the lowest point on the AE posterior wall) of EMP from the other part (south) of Croatia and to explain a possible connection between TMJ morphology and the type of food consumed.

The temporal components of the TMJ have been investigated by various methods (two- and three-dimensional) and materials (Ikai et al., 1997). In describing the complex anatomical and convex surfaces of the TMJ the three-dimensional methods are more informative than the two-dimensional linear measurements. Use of a three-dimensional method combining detailed anatomical observations with univariate treatment of particular characters sets the stage for a detailed multivariate study of temporal bone morphology (Lockwood et al., 2002; Terhune et al., 2007). CT and CBCT are often used in three-dimensional analysis of joint morphology (Kijima et al., 2007; Sümbüllü et al., 2012). However, CT (and CBCT) machines have limitations (Sümbüllü et al., 2012) because of their high cost, large footprint and high radiation exposure (research performed on living people). Furthermore, Lockwood et al. (2002) stated that quantitative shape of the temporal bone has been expressed often by dimensions and angles of the mandibular fossa. Cephalometric studies have often been used to compare position and dimensions of the glenoid fossa with craniofacial morphology (Baccetti et al., 1997; Pirttiniemi et al., 1990). Although the AE has convex and concave surfaces, measurements of simple AE parameters from lateral view (inclination, height, length) are easy to perform and replicated while three-dimensional measurement methods also require additional financing. For that purpose, the lateral skull photographs and radiographic images could be used, and also they are widely known to both museum and academic staff.

The primary aim of this study is to compare AE parameters of the EMP and the CP population. For this task, three different measuring methods will be used in order to reveal differences between the used methods and their (dis)advantages considering the measurement accuracy.

Null hypotheses were established as follows: there is no statistically significant difference between AE inclination, height and length of curved line from AE highest to the lowest point between EMP and contemporary Croatian population (CP). Also, there is no statistically significant difference between values obtained by different measuring methods.

2. Materials and methods

The study was performed on 30 specimens – human dry skulls from an early medieval period (9th–11th century), aged from 18 to 55 years subdivided in three age groups: 4 skulls (13.4%) aged up to 30 years, 17 skulls (56.6%) from 31 to 45 years, and 9 skulls (30.0%) were 46 years or older. Fourteen (46.7%) EMP specimens were males, while 16 (53.3%) of them were females (Table A.1). The skulls were a part of a bigger sample stored in the Anthropological Center of Croatian Academy of Sciences and Arts in Zagreb, Croatia. All skulls were excavated in the 20th century from archeological sites in south Croatia (Velim-Velistak, Radasinovci, Sveti Lovro-Sibenik, and Dubravice). The degree of preservation of excavated skulls varied greatly, from fully preserved skulls to the skulls of which only small fragments of the jaws were preserved. The skulls included in this study were completely preserved in the measured area without any damage caused by soil or water exposure (temporal articular eminence and fossa glenoidalis, meatus

Please cite this article in press as: Kranjcic, J., et al., Differences in skeletal components of temporomandibular joint of an early medieval and contemporary Croatian population obtained by different methods. Ann. Anatomy (2015), http://dx.doi.org/10.1016/j.aanat.2015.03.004