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Compensatory mechanisms in skull construction as a result of mandibular prognathic growth

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ABSTRACT
Mandibular prognathism is a gnathic defect that causes severe dysfunction of the stomatognathic system.
The aim of the study was to describe the compensatory mechanisms in the anatomical structure of the historical skull of a woman with severe mandibular prognathism, from the 'Kuronia' collection from the former 19th-century cemeteries of the Evangelical-Reformed Parish and the Evangelical-Augsburg Parish of St. Mary Magdalene in Wrocław.
The compensatory changes in the anatomical structure of the skull, mainly affecting the alveolar part of the mandible and the maxillary alveolar processes, were probably aimed at achieving functionally efficient interdental contacts in the upper and lower arches. Due to edentulism, it was not possible to describe the exact position of the teeth. However, from the preserved alveolar bone structures it was possible to approximate the axes of their inclination. The analysis of the defects of the stomatognathic system in historical populations can enrich the study of their biological condition, constituting a rich source of information on their lifestyle and nutrition.
Keywords: edentulism: prognathism; historical skull; compensation process.

INTRODUCTION

Prognathism occurred in fossil forms of hominids and in early forms of *Homo* but as a result of the evolutionary reconstruction of the facial part of the skull, the mandible and maxilla were retracted and in modern humans they are only slightly protruded anteriorly.

The stomatognathic system is a morphological and functional set of interacting tissues and organs of the oral cavity and the facial part of the skull that form a functional whole, controlled by the central nervous system. This dynamic system performs very important functions in the human body, such as chewing and initial digestion of food, swallowing, speaking, breathing, and maintaining posture. The postural function is achieved through the head's reactivity to signals from receptors and horizontal tracking through the dynamic connection between the skull, cervical vertebrae, clavicles, sternum, mandible and hyoid bone. The stomatognathic system also plays an important role in the expression of emotions through the mobility of mimic muscles and, importantly, in the alleviation of psychosomatic disorders through the function of teeth clenching and the activity of masticatory muscles in stressful situations known as bruxism. The stomatognathic system is also responsible for facial aesthetics. The effective implementation of these functions is determined not only by the activity of the temporomandibular joints and the entire neuromuscular system, but above all by occlusion, i.e. the interdental contacts of the teeth in the maxilla and mandible. The correct contact of the opposing teeth has a significant effect on the masticatory system and its functions [1, 2]. Mandibular prognathism is a genetically and functionally conditioned gnathic defect that causes serious dysfunction of the masticatory system, resulting in difficulties with chewing, swallowing, breathing and articulation [3, 4, 5, 6].

Studies of skeletal material with gnathic defects rarely address changes within the skull. In addition, although studies on compensatory mechanisms in the masticatory system and the influence of the living environment, diet and general condition of the population studied provide a great deal of information, most of them date back to the 1990s [7, 8, 9]. Interdisciplinary scientific cooperation is expanding knowledge in this field and is making it possible to explain the influence of the environment on the occurrence of changes in the stomatognathic system. Research on adaptation mechanisms in the human skeleton, especially the skull, can provide scientifically significant information [10].

The aim of the study was to identify, describe and analyse the effects of compensatory mechanisms on the anatomical structure of the skull in severe mandibular prognathism. The skull comes from the 'Kuronia' collection from the former cemeteries of the Evangelical-Reformed Parish and the Evangelical-Augsburg Parish of St. Mary Magdalene in Wroclaw. The burials took place in the period between 1862–1944.

CASE REPORT

The most characteristic feature of this skull is the disproportionate size of the maxilla and mandible. In the examined skull

(KA1368) of a woman who died at senile age (estimated age 60–65 years) [7], significant underdevelopment of the maxilla is clearly visible in the vertical, transverse and sagittal dimensions, with the presence of a mandibular prognathism (Fig. 1, 2). Mandibular prognathism is most often a genetically determined gnathic defect. It can be described as both morphological and functional as it causes severe dysfunction of the masticatory system, associated with difficulties in chewing, swallowing, breathing and articulation. Maxillary hypoplasia, especially in the vertical dimension, significantly reduces the height of the lower part of the face.

FIGURE 1. The skull from the 'Kuronia' collection (1862–1944) – sagittal view

FIGURE 2. Disproportion in size of maxilla and mandible in the examined skull (KA1368) with horizontal position of foramen mentale

Excessive elongation of the mandibular body and ramus prevented proper tooth contact in the opposing dental arches. The effect of the defect was exacerbated by the narrowing of the upper dental arch (the alveolar arch was assessed in the examined skull due to the lack of preserved teeth) in the deficient bone bases of the maxillary alveolar processes (Fig. 3). Therefore, for functional reasons, there were changes referred to as compensatory changes, which are considered in the context of joint compensation in the temporomandibular, dentoalveolar and dental joints [1].

FIGURE 3. Maxilla and mandibular fossa on the skull

In the described female skull, successive anatomical changes are visible, aiming at achieving a functional occlusion. Due to the very high severity of the gnathic defect, clear features of all compensatory mechanisms can be observed.

In terms of joint compensation and changes in the structure of the temporomandibular joints, the presence of a large articular surface, forming the anterior section of the mandibular fossa, was noted, almost perpendicular to the zygomatic arch (Fig. 3).

The articular tubercle, a bulge with individually inclined slopes, is relatively well developed. However, it can be assumed that safe condylar movements could have taken place mainly during rotation if the activity of the articular ligaments was efficient. On the other hand, during translation, the condyle may have passed over the top of the articular tubercle, causing habitual dislocation of the mandible. Mandibular prognathism is often associated with compression in the temporomandibular joints, as evidenced by the flattened condyles in the described skull. Another mechanism of individual morphological and functional adaptation is dentoalveolar compensation [2].

Changes in the anatomical structure mainly affected the alveolar part of the mandible and the atrophied maxillary alveolar processes. The shape of the upper dental (alveolar) arch is trapezoidal rather than elliptical. The alveolar axes, especially of the anterior teeth, are set divergently outwards towards the vestibule. On the other hand, the mandibular body is positioned extremely obliquely in the lingual direction so that the upper (alveolar) edge is on the lingual side. This suggests that the lower teeth were tilted towards the oral cavity in order to make contact with the upper teeth. The mental foramina are located in the horizontal plane (Fig. 2) on the external surface of the mandibular body, which is almost horizontal in this skull.

Dental compensation is also characteristic of skeletal class III. Due to the lack of preserved teeth (Fig. 1) in the described skull, it is not possible to say with certainty whether the tooth overlap was correct or reversed. However, based on the analysis of the preserved alveoli, it is possible to approximate the long axes and the position of the teeth. In the maxilla, the anterior teeth were probably tilted strongly towards the vestibule in order to widen the upper dental arch. In the mandible, however,

they were extremely tilted lingually. This is particularly evident from the preserved alveoli of the incisors, whose long axes are almost horizontal. The long axes of the lower anterior teeth were not perpendicular to the mandibular abduction axis, which may also have contributed to their loosening due to occlusal overload and premature loss. On the other hand, in the posterior section, the axes of the maxillary and mandibular teeth suggest the presence of crossbite, which not only can cause unfavourable interference between the opposing teeth during mandibular movements but is also considered to be one of the causes of dysfunction in the temporomandibular joints.

DISCUSSION

The compensatory processes in the described adult female skull included all 3 mechanisms: articular compensation, dento-alveolar compensation and dental compensation. They occurred in all directions of cranial growth, namely transversely, vertically and horizontally, and were aimed at achieving the best possible functional efficiency of the masticatory organ [2]. These processes could have progressed and intensified due to the intravital loss of subsequent teeth. The consequence of tooth loss was the loss of bone tissue, the characteristic course of which in the maxilla and mandible could have exacerbated the defect [11].

Particularly noteworthy is the compensation manifested by the developmental change in the height and inclination of the mandibular body, the edge of which, together with the alveoli, was positioned almost horizontally in the lingual direction. This growth trend should influence the modification of the occlusal relationships between the upper and lower teeth in the sagittal plane.

Joint compensation is a characteristic tendency of skeletal class III. It is a continuous process and can occur throughout life because the function of the temporomandibular joint is closely related to occlusal conditions. As the masticatory system matures, the occlusal relationships influence the development of the cranial bones, especially the position of the mandible and the function of the temporomandibular joints [12]. In the described skull, it is also likely that these processes took place during puberty and growth and then continued due to the loss of teeth, leading to an exacerbation of the defect. This is due to the naturally occurring processes of characteristic bone loss in the maxilla and mandible as a result of tooth loss. There is an articular connection between the U-shaped mandible and the 2 temporal bones and this is the most important connection due to the dynamic nature of the functions of the masticatory system. Successive connections between the temporal, occipital, parietal and other bones allow the transfer of large occlusal loads [13, 14].

The position of the teeth and their interrelationships are essential for the proper functioning of the temporomandibular joints. In the described case, the change in the long axis of the teeth to a more horizontal one probably resulted in an excessive load on the temporomandibular joints. Therefore, the morphology of the condyles shows features of flattening, which may indicate compression in the temporomandibular joints. Occlusal forces can change the shape of the mandibular condyle throughout life. The architecture of dental arches and the shape of teeth are also closely related to their functions. However, when there is a gnathic defect, nature tends to make changes to ensure optimal function. In the described skull, the underdevelopment of the maxillary bones and a very large mandible did not allow correct occlusal contact between the maxillary and mandibular teeth. As a result, the axis of the long mandibular teeth tilted significantly in the lingual direction, as can be seen from the preserved alveoli. In this way, complex compensatory over the course of a lifetime resulted in some functional capacity in terms of chewing, speaking, swallowing and other functions of the stomatognathic system.

The formation of the elements of the human masticatory apparatus depends on many factors, therefore the analysis of their changes can provide a number of important clues about the life of prehistoric and historic populations. The analysis of bone changes in the masticatory system, which is one of the most important elements of the digestive system, may not be as good an indicator of living conditions and their sensitive measurement for anthropologists and bioarchaeologists as, e.g., body height [7]. However, if it is included in the methods used to determine the level of pressure of environmental factors, it will enrich research and the level of analysis of changes in the biocultural system of ancient and modern populations, providing information on their lifestyle and nutrition.

The presented compensatory mechanisms in the skull construction resulting from the prognathic growth of the mandible in a woman from the studied skeletal population 'Kuronia' showed the validity of interdisciplinary research aimed at the reconstruction of the biological condition of a 19th-century Wrocław inhabitant. As a result of edentulism, probable temporomandibular joint dysfunction and reconstruction of the mandibular body, the process of food intake was disturbed, which could have resulted in vitamin and mineral deficiencies, gastric problems and problems with clear phonation, as well as possible chewing problems and pain radiating to the temples, occiput and nape of the neck. In addition, the increased load on the temporomandibular joints and the position of the head forced by the size and weight of the mandible may have influenced degenerative changes and dysfunction of the atlantooccipital joint. Studies in a contemporary comparison group confirm that the symptoms may have been similar in historical populations [10].

CONCLUSION

All 3 mechanisms of compensation for the gnathic defect, aimed at obtaining better conditions for the performance of the functions of the masticatory system, occurred in the preserved skull. It was particularly important to obtain functionally efficient interdental contacts.

REFERERENCES

1. American Academy of Prosthodontics. The glossary of prosthodontic terms: ninth edition. J Prosthet Dent 2017;117(5S):e1-105.
2. Slavicek R. The masticatory organ: function and dysfunction. Klosterneuburg: Gamma Medizinisch-wissenschaftliche Fortbildungs-AG; 2002. p. 50-8, 188-92.
3. Zere E, Chaudhari PK, Sharan J, Dhingra K, Tiwari N. Developing class III malocclusions: challenges and solutions. Clin Cosmet Investig Dent 2018;10:99-116. doi: 10.2147/CCIDE.S134303.
4. Singh GD. Morphologic determinants in the etiology of class III malocclusions: a review. Clin Anat 1999;12(5):382-405. doi: 10.1002/(SICI)1098-2353(1999)12:5<382::AID-CA9>3.0.CO;2-0.
5. Genno PG, Nemer GM, Zein Eddine SB, Macari AT, Ghafari JG. Three novel genes tied to mandibular prognathism in eastern Mediterranean families. Am J Orthod Dentofacial Orthop 2019;156(1):104-112.e3. doi: 10.1016/j.ajodo.2018.08.020.
6. Doraczynska-Kowalik A, Nelke KH, Pawlak W, Sasiadek MM, Gerber H. Genetic factors involved in mandibular prognathism. J Craniofac Surg 2017;28(5):e422-31. doi: 10.1097/SCS.0000000000003627.
7. Buikstra JE, Ubelaker DH, editors. Standards for data collection from human skeletal remains. Arkansas: University of Arkansas System. Arkansas Archeological Survey; 1994.
8. Hodges DC. Temporomandibular joint osteoarthritis in a British skeletal population. Am J Phys Anthropol 1991;85(4):367-77. doi: 10.1002/ajpa.1330850402.
9. Koppe T, Schöbel SL, Bärenklau M, Bruchhaus H, Jankauskas R, Kaduk WMH. Factors affecting the variation in the adult temporomandibular joint of archaeological human populations. Ann Anatomy 2007;189(4):320-5. doi: 10.1016/j.aanat.2007.02.018.
10. Bumann A, Lotzmann U, Mah J. TMJ disorders and orofacial pain: the role of dentistry in a multidisciplinary diagnostic approach. Stuttgart: Georg Thieme Verlag; 2002.
11. Felton DA. Edentulism and comorbid factors. J Prosthodont 2009;18(2):88 96. doi: 10.1111/j.1532-849X.2009.00437.x.
12. Roberts WE, Stocum DL. Part II: temporomandibular joint (TMJ)-regeneration, degeneration, and adaptation. Curr Osteoporos Rep 2018;16(4):369 79. doi: 10.1007/s11914-018-0462-8.
13. Tyan S, Park HS, Janchivdorj M, Han SH, Kim SJ, Ahn HW. Three-dimensional analysis of molar compensation in patients with facial asymmetry and mandibular prognathism. Angle Orthod 2016;86(3):421-30. doi: 10.2319/030915-142.1.
14. Spalj S, Mestrovic S, Lapter Varga M, Slaj M. Skeletal components of class III malocclusions and compensation mechanisms. J Oral Rehabil 2008;35(8):629-37. doi: 10.1111/j.1365-2842.2008.01869.x.