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JOINT FUSIONS IN PALAEOPATHOLOGY: DIAGNOSIS AND EPIDEMIOLOGY

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Introduction

Man of past populations - likewise the members of modern societies - is biological and socio-cultural being. Archaeological studies can help us to get more knowledge about the past populations' life primarily through the recovery and analysis of the material culture and environmental data that they have left behind. The analysis of the populations would not be complete without the science of 'biological being', and biological anthropology is one of the candidates who focuses on this scientific approach. Its goal is to reconstruct the past societies on the basis of their biological characteristics, its analytical results let us to get more information about the life of ancient populations. Palaeopathology is the discipline of ancient diseases; its results help us to understand the natural history and progression of the diseases.

Ankyloses are one of those pathological lesions that nowadays appear seldom in the developed countries, thus getting more information about their diagnostic or epidemiological characteristics may be helpful both in the biological reconstruction of the past populations and in the utility of the medicine.

Osseous joint ankyloses are quite rare, but easily recognizable pathological conditions. Fusions of joints may occur as a result of several diseases (e.g. trauma, infection, developmental defects, metabolic diseases, seronegative arthropathies), but the development of them is rarely described in developed countries, thanks to diagnostic techniques that allow early detection and treatment of the underlying disease. Evidence of the natural history and progression of the disease is now primarily studied through the observation and analysis of osteoarchaeological specimens, and medical reports or books dating from the pre-antibiotic era. In cases of bony fusions the joints or surrounding soft tissue elements becomes rigid, fibrous, later bony ankyloses develop.

The term ankylosis may be approached from different points of view. It may be interpreted in a functional aspect; on the other hand, it may refer to certain anatomical alteration, when the bony ends of joints are fused together by an osseous bridge.

Concerning the human skeletal alterations, both modern and osteoarchaeological samples exhibit characteristic joint fusion. In the latter category mainly osseous ankyloses can be observed, distortion of the articulations' bony elements or fusion of the adjacent joint surfaces can be recognized. The analysis of predilection sites and typical macroscopic symptoms can help investigators to find the correct aetiology of the alterations.

Aims

Osseous ankyloses are quite rare in the modern medical practice, thanks to diagnostic techniques that allow early detection and treatment of the underlying disease. Evidence of the natural history and progression of the diseases is now primarily studied through the observation and analysis of osteoarchaeological specimens and medical reports or books dating from the pre-antibiotic era.

My PhD-studies focus on diagnostic and epidemiological approaches of the phenomenon of ankyloses. After making the database of ankyloses the osteoarchaeological investigations planned to be done on the following axes:

- Is it possible to find special characteristics during a systematic analysis of ankyloses, which can help both confirm our previously established diagnosis and find the exact etiological background?
- How can the utilization of medical imaging techniques help us to clarify the characteristics of different ankylosis cases? How can we integrate the results of recent medical imaging technique studies into the palaeopathological context?
- Are histological analyses informative for us to make a proper description of development of the ankylosis? Can we differentiate different types of ankylosis cases on the basis of histological differences?
- In case of the co-existence of joint ankylosis and other pathological conditions in osteoarcheological material, the analysis of the associations among these diseases may be helpful in the understanding of the interaction and development of human diseases?
- Is there any difference between our results and those found in medical/ palaeopathological literature according to the epidemiological characteristics?

Material and methods

During our analysis, anthropological materials from the Great Hungarian Plain were examined. The skeletal remains represent five archaeological periods of the Carpathian Basin; the oldest specimens are dated back the Sarmatian period (1-5th c. AD), while the most present

series are dated to the early modern times (18th c. AD). Summarizing the data, we can say that skeletal remains of 10976 individuals have been included the examined material.

Basic anthropological data (sex, age at death, age categories) were available for us from previously carried out anthropological studies.

During the recording of pathological conditions, we utilized specific record sheets. The three types of recording sheets include the skeletal representation of the spine, the upper extremities and the rib cage, and the lower extremities together with the pelvic region. In the inventory sheets, the chronological period, the site name (abbreviations), the grave/object and registration numbers, the age at death and sex were first registered. In addition, the pathological conditions (precise localization, laterality, type, description and developmental stage) observed in the bones were recorded, in case of necessity a short description of the pathological alterations has been written too. Another written database is also made, it contains the localization and characteristics of ankyloses; the additional pathological lesions are also collected in this database.

Beside the macroscopic analyses results of medical imaging techniques were also taken into consideration during our analyses. Classical X-ray and computed tomography (CT) data were utilized. Virtual 3D reconstructions are made; with the utilization of this technique we can gain more information about a given moment of the development of a disease.

In some of our specimens histological examinations were also utilized, thin sections were prepared for histological analysis, hematoxylin and eosin stain was used.

Concerning some cases, results of previously made additional analytical techniques (e.g. DNA analyses) were also utilized to confirm our hypothesis.

Results

During our analyses single or multiple ankyloses were found in the skeletal remains of 346 individuals, they are associated with numerous nosological categories. Two anatomical-functional types of the ankyloses were found. The majority of the cases are functional osseous fusions, but some tibiofibular and rib fusions can be interpreted as functional ankylosis, the joint itself is not involved in these cases.

1. Concerning the aetiological categories, the developmental defects are demonstrated in the biggest number, the alterations were seen in all age categories. All of these fusions are localized to the axial skeleton, *synostosis vertebralis*, sacralisation, various sternal

segments ankyloses and functional fusions of the ribs were recognizable. Other nosological groups provided ankyloses as well, it was possible to diagnose skeletal fusions associated with degenerative, traumatic, infectious, metabolic and rheumatic diseases. Concerning the characteristics (age and sex distribution, laterality, localization) of the ankyloses, our findings, except one ankylosis type (LV5 – S1 sacralization) answer to the descriptions found in the medical or palaeopathological literature. In the LV5 – S1 sacralization cases a very strong male predominance is seen, the imbalance may be explained by fact that the determination of the sex was not possible in several individuals.

2. One of our aims was to realize, whether a systematic analysis helps us to find special, disease-associated alterations. We found additional signs in two nosological groups (diffuse idiopathic skeletal hyperostosis (DISH), tuberculosis); these may help us to diagnose the disease in a more efficient way.

   – In DISH cases, the ossification of certain ligaments may be diagnostically useful alterations. In the majority of the cases the *ligamentum flavum* and supraspinous ligament ossification were recognizable, but the ossification has developed at other sites as well. The presence of these and other observed lesions (e.g. extra-axial enthesopathies) has raised a new question. On the basis of the diagnostic criteria of Waldron (2009), the differentiation and separation of DISH and early-stage DISH cases seems to be very artificial, the very thin line between the two categories is based on the difference of only one alteration (ossification of the anterior longitudinal ligament). In those cases, where fusions at least four adjacent vertebral bodies are present, the diagnosis is DISH, while if less than four contiguous vertebrae are fused, the diagnosis is early-stage DISH. Concerning other spinal and extra-spinal alterations there's no difference between the two categories, diffuse ossification and calcification processes are found in all cases of the two categories. Interestingly enthesopathies were not seen in all cases, but ossification in the vertebral foramen (possibly as a result of *ligamentum flavum* ossification) is visible in all of them. Although the little number of cases does not let to draw unequivocal conclusions, on the basis of these facts, diagnostic criteria for DISH and early-stage DISH may need to be reconsidered in the future. In our previous opinion, the diagnosic criteria of DISH in osteoarcheological samples possibly need to be expanded, and some pathologic features (e.g. ligamentum

flavum ossification) and patterns (number and relation of vertebrae with complete and not complete fusions) should be taken into account. As we found characteristic radiological signs (e.g. ‘coating phenomenon’ at the anterior ligament ossification), we would like to underline the importance of the utilization of medical imaging techniques in those cases, when lack of the predilectional site(s) or pathognomic sign(s) impedes the precise diagnosis.

- The second etiological group, where interesting characteristics (‘image mirror’ lacunar lesions of the meta- and epiphyses) were found is the tuberculosis. Probable TB-associated knee fusions were found in two specimens, and we would like to point out those medical imaging techniques, especially high precision of the reconstruction opens up new possibilities for approaching real anatomy. In the medical practice mainly 2D reconstruction analyses are accepted to make a proper diagnosis. We used these different directional 2D CT images to find the background etiology resulted in ankylosis, but our 3D high precision reconstructions helped to compare interior alterations to those ones found in early medical literature

3. We found characteristic coexistence between the ankyloses and other diseases in some aetiological groups.

    - developmental diseases may have appeared as a single ankylosis, but in numerous cases one or more additional developmental defects were recognizable in the skeleton. It correspond in the data found in both the medical and palaeopathological literature;
    - ankyloses associated with degenerative processes presented strong correlation with traces of other degenerative diseases, spondylosis deformans and degenerative osteoarthritis were found in the majority of these fusion cases;
    - strong correlation between the vertebral fractures and osteoporosis of the skeletal elements are recognizable;
    - in DISH cases characteristic ossification of certain ligaments are present, the ossification of the *ligamentum flavum* and the supraspinal ligament may be in strong association with the development of DISH; the presence of them may let us to use these alterations as diagnostically useful criteria.

4. Concerning the epidemiological approach, the strict prevalence of a disease is not given by our study. The lack of complete population statistics and the facts that the ankylosis is only a special phenomenon or appearance form of the diseases hinder the strict calculation. However, special tendencies as conclusions can be drawn; they correspond to those characteristics that are found in the literature.

   Our data on distribution of DISH corresponds to those found in the literature. The onset of the disease is at younger age (Adultus age category), but the majority of the cases, where well-developed skeletal changes are present, belongs to older individuals (Maturus and Senium age categories). The mid-thoracic spine is involved the most, and disease continues toward the upper thoracic and lumbar spine in some cases. In our cases DISH affected only males, no females are found even among the early-stage DISH cases.

   Classical appearance of ankylosing spondylitis is found, and only males are involved in the disease. Skeletal alterations affected the lower lumbar vertebrae in the majority of cases; in one extensive case almost the entire spine is ankylosed by syndesmophytes and zygapophyseal joint fusions. Individuals belonging to the Maturus and Senium age categories demonstrated the classical alterations associated with AS, younger individuals (at least with severe osseous alterations) are not affected.

   Concerning the presence of tuberculous alterations, specific characteristics are seen. The development of bone fusions in the skeletons suggest that the disease exhibited in rather chronic than acut form, healing processes refer to the fact that the involved people survived the disease. Beside the pathognomic spinal Pott's disease, lower limbs and girdles are also demonstrate ankyloses where TB is the most probable aetiological factor. Although the small sample size impedes the precise analysis, the lower thoracic and upper lumbar segments of the spine are affected the most frequently in our analytical sample. Both the disc joints and the facet joints were involved in all of our cases; zygapophyseal joint fusions present a balanced development according to laterality.

   The alterations developed twice frequently in females than in males. Concerning the age distribution, the Adultus and Maturus age category is the most represented, vertebral fusions associated with tuberculosis were found only in two individuals belonging to the Senium category. If we separate the two sexes, it is clearly seen that the peek is found in the Adultus age category in females, while the cases belonging to a male individual are more represented in the older age categories.

5. Concerning the utility of the diagnostic tools, there is a significant difference between the analytical techniques. Classical macromorphological examinations are unavoidable and useful techniques in most of the cases. Medical and palaeopathological diagnostic criteria or descriptions were applicable and reliable sources, and the underlying disease can be found with certainty.

   – Medical imaging techniques were useful diagnostic tools. Although X-ray images revealed the interior structure of the involved bones, no diagnostic traces were found in a remarkable portion of the images. However, the lack of certain signs excluded several diseases as an etiological factor. Computed tomography proved to be more useful than roentgenograms. As during the scanning numerous pictures will be created, the superimposition effect can be removed, bone tissue is examinable slice by slice. Additional 2D reconstructions gave us a chance to precise the appearance of a pathological lesion. Particular 3D reconstructions created with TIVMI software allowed for us to find the very precise morphological appearance of some rare pathological conditions (tuberculous osteomyelitis and arthritis of the knee). The combined use of radiological techniques, modern medical descriptions and books or reports from the pre-antibiotic era is a useful diagnostic method.

   – We did not find diagnostically useful traces during the histological analyses. As the development of the true bony ankyloses may take a long time, mature bone tissue of normal structure can develop in different diseases.

Perspectives

Osseous joint ankyloses are quite rare, but easily recognizable pathological conditions. Joint fusions associated with numerous diseases (e.g. trauma, infection, developmental defects, metabolic diseases, seronegative spondylarthropathies) were found; diagnostically, morphologically, diagnostically and methodologically important characteristics are presented in the dissertation.

As a result of the present examination new possibilities have arisen, these axes may help us in the biological reconstruction of man of past:

– more precise histological and medical imaging analyses need to be done to investigate the ankyloses;

- examination of those early-stage alterations need to be done which may be in association with ankyloses;
- the calculation of a disease's prevalence would be informative, it may lead to precise comparison of present and past populations;
- the co-existance of DISH and other diseases with ligament ossification (ossification of ligamentum flavum and ossification of posterior longitudinal ligament) are present in both medical and palaeopathological literature. Further palaeopathological analyses of the associations among these diseases may be helpful in the understanding of these diseases;
- comparative analysis of disease-specific ankylosis prevalences (*e.g.* in cases of DISH, AS, TB) in ancient populations can furnish relevant information about the past and the evolution of these pathological conditions.

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