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THE POSSIBLE MANIFESTATIONS OF SCURVY ON SKELETAL REMAINS DATED TO 3800–3700 BC

ABSTRACT: *The presented report describes the skeletal remains of a young man with multiple pathological changes, dated to between 3800–3700 BC.*

The studied skeletal remains were subjected to classical anthropological analysis. The palaeopathological study was based on detailed macroscopic examination supplemented by histological and radiological examinations.

In addition to the disorder of flat cranial bones, dental developmental defects, traces after periodontal and sinus maxillaris inflammation, partially fractured left rib and fracture of the first lumbar vertebra were found on this skeleton. Based on the mentioned examinations, this finding was evaluated as one of the possibly oldest cases of scurvy in Europe.

KEY WORDS: *Endocranial lesions – Eneolithic – Palaeopathology – Scurvy – Traumas*

INTRODUCTION

Scurvy is a disease caused by the lack of vitamin C (L-ascorbic acid) in the human organism. Unlike most animals, humans can not synthesize vitamin C in the body because they lack the important enzyme L-gulonolactone oxidase. For this reason, the amount of vitamin C depends exclusively on dietary intake. This vitamin is an important component of many oxidative-reducing processes in the body. In its absence,

molecules of collagen are unstable and are unable to form normal higher structures. Vitamin C deficiency will be manifested especially in the quality of basal membranes, blood vessel walls, ligaments, cartilages, bones, etc. (Wheeler *et al.* 1998).

In palaeopathology, the diagnosis of scurvy is quite difficult. The diagnostic criteria for this disease have not been uniform (Snoddy *et al.* 2018). Pathological changes induced by avitaminosis C are most pronounced on growing skeletons, therefore scurvy is

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mainly described in children (Brickley, Ives 2006, Klaus 2014, Stark 2014). For adults, however, the number of previously documented cases of scurvy in historical populations (Crist, Sorg 2014) does not correspond by far to literary sources. The most palaeopathological findings of this disease come from the modern age (Mays 2014) although Ebers' papyrus (about 1500 BC) reveals that scurvy was known to the Ancient Egyptians. In the historical context, vitamin C deficiency is associated primarily with the period of great overseas discovery in the 15th and 16th centuries, when European sailors lacked fresh fruit and vegetables on their long voyages. Scurvy is therefore considered a typical disease of sailors, possibly associated with long-term famine accompanying natural disasters and wars (Armélagos *et al.* 2014, Pimentel 2003).

From this point of view, the aforementioned skeletal remains of the young man are further direct evidence of the possible occurrence of scurvy, and their dating to the Neolithic period of 3800–3700 BC is noteworthy.

MATERIAL

The studied skeletal remains originated from the H 801 grave in Podivín-Rybáře (Břeclav District, South

Moravian Region, Czech Republic). Radiocarbon dating has pointed to the chronological relevance of all the grave findings to the Eneolithic Era, that is associated with the Funnel Beakers ((TRB, after German Trichterbecher) in the region. However, no ceramics were found in the locality to match the TRB pottery. The value from radiocarbon measurement of the individual from the studied grave is 5020 ± 35 BP (sample No. Poz-71869) which, after calibration according to the OxCal model (Bronk Ramsey 2001), indicates a significant time dispersion with respect to the plateau in the IntCal 2020 calibration curve (Reimer *et al.* 2020) for this measured value (*Figure 1*).

However, when compared to radiocarbon data from other burials, the most likely time interval of the funeral horizon is between about 3800 and 3650 of calBC. The individual from grave H801 most probably corresponds to an interval of about 3800 to 3700 of calBC. Six of the seven skeletons found on the site were placed in a position on their backs (dorsal decubitus), with the upper limbs stretched along the body, with a W-E body orientation. One skeleton was stored in the crouched position. All the graves were under a topsoil layer, but it was impossible to identify the grave pit in any of them. Burial in a supine position without grave equipment is a completely new phenomenon from the standpoint of agricultural prehistory. It is also known

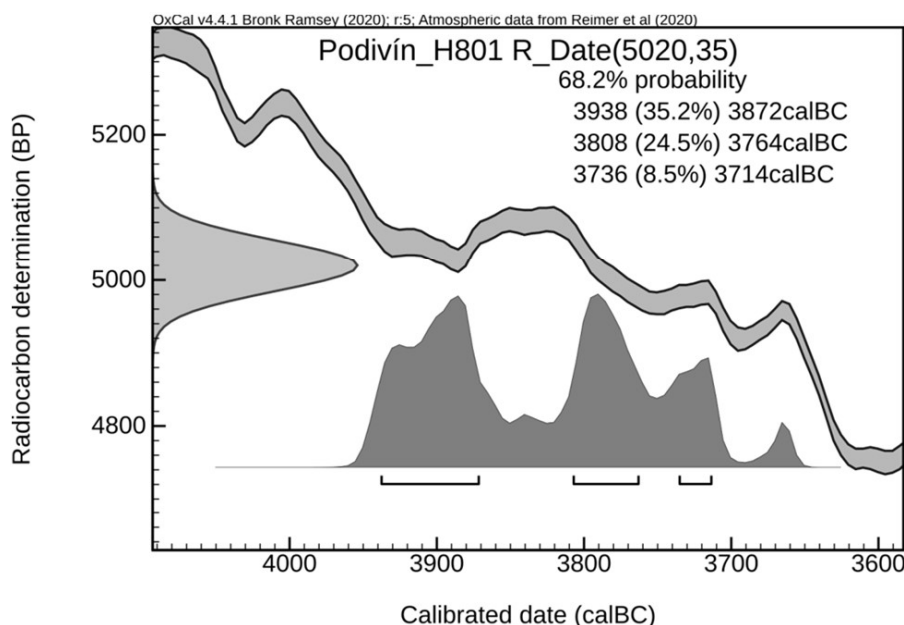


FIGURE 1: Calibrated C14 date from the grave 801 (graphics by František Trampota).

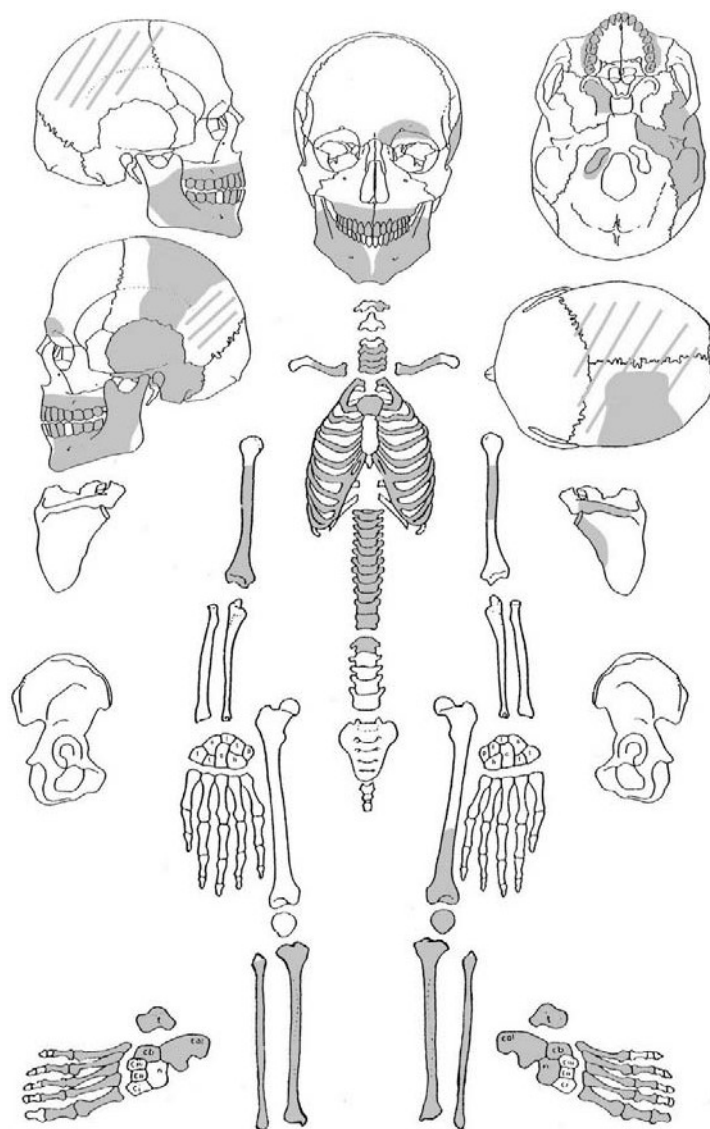
in the Early Eneolithic from smaller burial clusters in Prostějov-Čechůvky (Drozdová 2011, Šmíd 2011), Modřice (Šmíd *et al.* 2018) or Maissau in Lower Austria (Schmitsberger 2019) and from several others.

The examined skeleton came from a small osteological collection that included the incomplete remains of seven individuals (7–8 year old child, three adult males and three adult females). The skeletal remains from the H 801 grave belonged to a 20- to 25-year-old man. The missing parts of the skeleton were caused by earlier excavation work done without an

archaeologist's supervision. Only a few fragments of the bones of the neurocranium and jaw have been retained from the skull. The teeth were almost complete, only the lower incisors were missing. The postcranial skeleton was also in fragments (see *Scheme 1*).

METHODS

The studied skeletal remains were first subjected to classical anthropological analysis. The sex of the



SCHEME 1: Scheme of preservation of the skeleton of the individual from grave No. 801. The preserved parts of the bones are marked by grey colour.

individual was determined according to metric evaluation of the talus (Novotný 1985) as hypomasculine. According to the metric data of the tibia, using the method of Iscan, Miller-Shaivitz (1984), the sex of this individual was determined to be male with a sufficient confidence interval in all the measured data. The determination of the age (20–25 years) of the studied individual was carried out according to the maturation of the skeleton, according to Čihák (1987) and Scheuer *et al.* (2000), based on ossification of the proximal epiphyses in the tibiae and sternal end of the clavicle.

The H 801 individual was most probably about 161 to 166 cm tall according to the length of tibia and fibula (Sjøvold 1990). The femurs, which provide the most accurate height estimation, are missing. Analysis of the preserved teeth did not show the presence of dental caries. The denture carried traces of hypoplasia of the tooth enamel (see below). Overall, the dentition of this individual has mild dental calculus deposits and a degree of dental abrasion of the enamel and dentine, corresponding to his age. Imprints were taken from the first and second lower right molars, using stomatological impression materials with high resolution parameters – Affinis light body / regular body (manufacturer Coltène AG, Switzerland) for further analysis for food reconstruction (for methodology, see Jarošová *et al.* 2006, Lalueza *et al.* 1996, Pérez-Pérez *et al.* 1994). Subsequent making of tooth casts and their processing was carried out by scanning electron microscope (SEM).

The palaeopathological study was based on anthropological analysis, and on detailed macroscopic

examination. All pathological changes were documented in detail. Histological (half-cut sections of bone tissue stained with toluidine blue) and radiological examinations were performed for the needs of differential diagnosis.

For the evaluation of osteopathological changes, the criteria of Aufderheide *et al.* 1998, Horáčková *et al.* (2004), Ortner, Putschar (1985), Ortner (2003) and Steinbock, Stewart (1976) and were used, together with a comparison with similar cases from current clinical practice (Dungl 2005, Vyhnanek 1998).

RESULTS

Pathological changes were found on the skull, as well as on the postcranial skeleton on the skeletal remains of the 20- to 25-year-old man from grave no. 801.

The bones of the cranial vault are most affected on the skull. On the internal surface of a fragment of the left half of the squamous part of the frontal bone, there is a circular depression of 5–6 mm diameter with an irregularly wavy bottom. The defect is lined with small pitting, with rounded edges of individual apertures, and has a similar structure as *granulationes arachnoidales* cause (Figure 2). In addition, on the inner surface of this bone, there are thin, richly branched grooves which only affect the *lamina interna cranii* (Figure 3). The whole squamous part is considerably thickened. At the bone quarry, it is evident that in this case the diploe is increased, whereas the both laminae have a normal appearance (Figure 4). The maximum bone

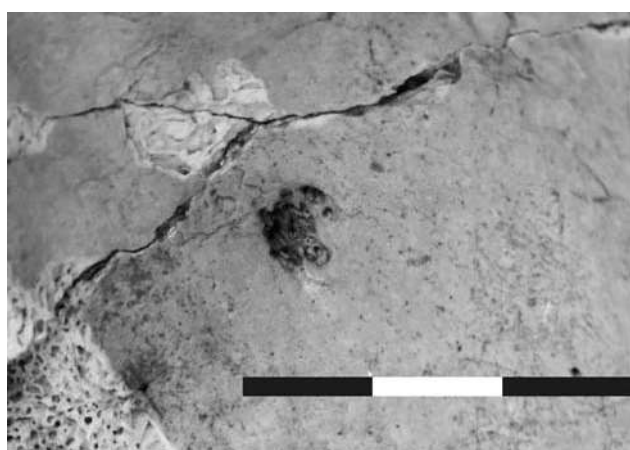


FIGURE 2: Deep depression on the inner surface of the cranial vault (photo by Jana Vachová).

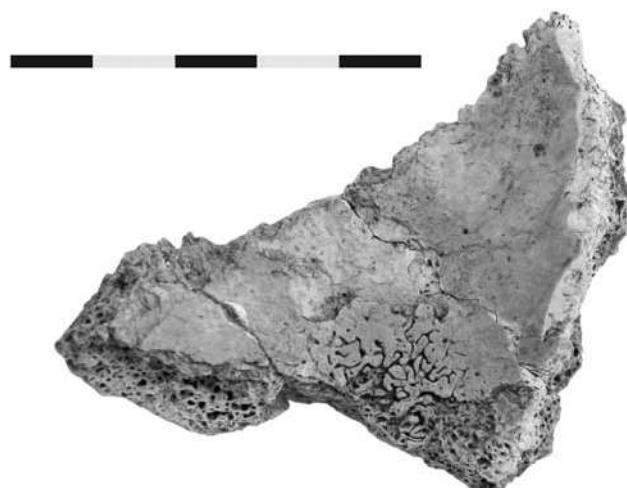


FIGURE 3: Shrub-like branching of sulci arteriosi on lamina interna cranii (photo by Jana Vachová).

thickness is up to 15.5 mm, the minimum at *sutura coronalis* is only 8.6 mm. The right part of the squamous part of the frontal bone has not been preserved, so it can not be ascertained whether it had symmetrical thickening.

Pathological changes are also evident on a small fragment of one of the parietal bones where, near the *sutura sagittalis*, there is an atypical formation of the terminal parts of the impressions of the meningeal vessels in the form of irregularly coiled channels disturbing the *lamina interna*. In a series of semi-thin

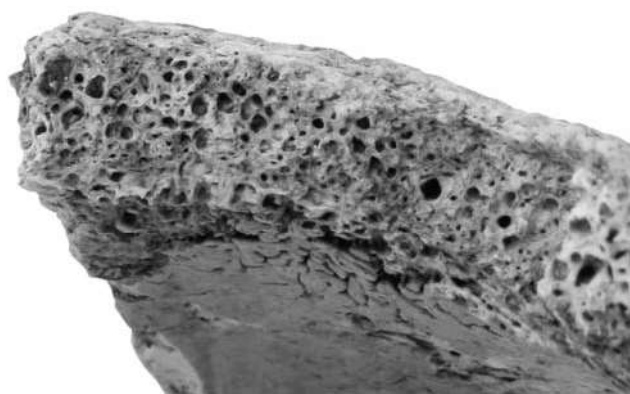


FIGURE 4: Fragment of the parietal bone with significant bone tissue hypertrophy, probably caused by ossification of the subdural haematoma (photo by Jana Vachová).

histological sections of bone tissue stained with toluidine blue, bone trabeculae with activity of osteoclasts are evident. In addition to the lacunae after osteoclastic action, islets of fibrous stroma are visible between bone trabeculae (Figure 5). It cannot be completely ruled out that these may be signs of decomposition or taphonomic changes, but based on many years of experience, we assume that this is just the fibrous stroma.

On the studied skull, the signs of congenital and acquired dental diseases could be observed on the preserved parts of the jaws. A typical developmental defect are the palato-radicular grooves on the second incisors of both upper jaw (Ash, Nelson 2003). It is generally assumed that this is a developmental disorder of the Hertwig epithelial vagina, or an attempt to create another root of the lateral incisor (Lee *et al.* 1968). Among the dental disorders, the persistence of the second milk molars on both sides of the lower jaw can also be counted. The persistence of milk teeth in adulthood is likely to be related to the bilateral agenesis of the lower second premolars, as seen from X-rays of the denture (Figure 6). In addition to developmental defects, traces of chronic inflammation of the dental apparatus (*parodontitis*) can also be seen on the jaws of the studied skeleton. It shows the scarred edges of dental alveoli, with a number of minor perforations, especially on the external side of the upper jaws (Figure 7).

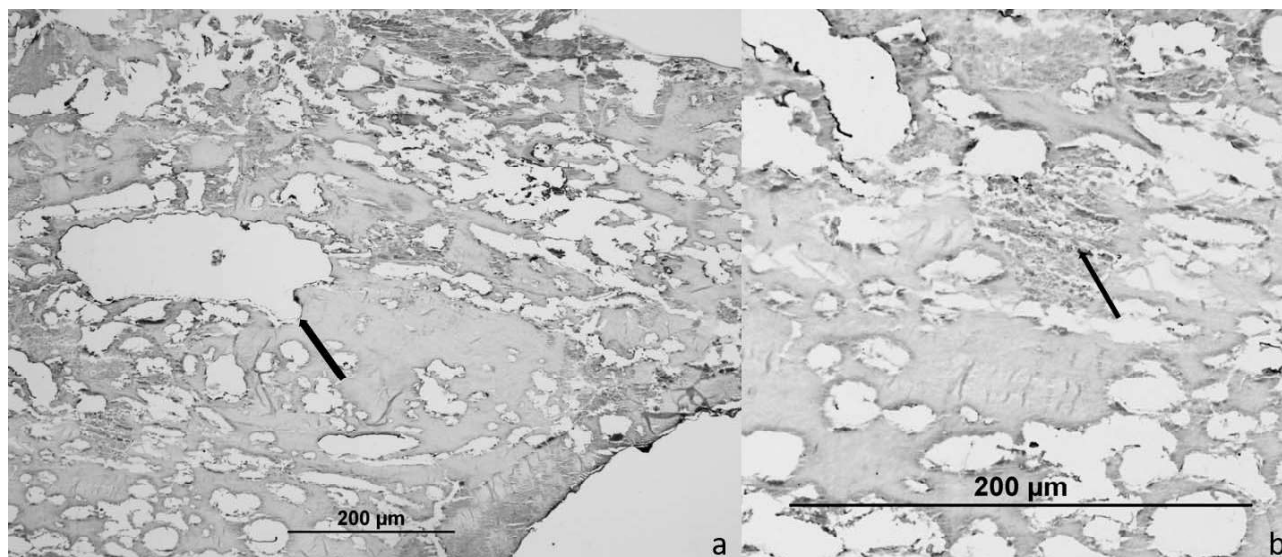


FIGURE 5: On a series of semi-thin histological sections of bone tissue stained with toluidine blue, bone trabeculae, whose structure is somewhat disturbed by osteoclast activity, are visible (a). In addition to the lacunae after osteoclastic action, islands of fibrous stroma are visible between the bone trabeculae (b) (photo by Alena Němečková).

Dental enamel hypoplasia is considered to be a non-specific manifestation of childhood illness in palaeopathology (Goodman, Armelagos 1985). On the frontal teeth of the examined skeleton, transverse hypoplastic grooves can be observed. According to localisation of hypoplastic lines, it is possible to estimate the origin of this condition to approximately 3.5 to 4 years of age (Reid, Dean 2000).

Pathological changes are also evident in the right *sinus maxillaris* (*sinusitis maxillaris*). At the bottom of this paranasal cavity, the posterior superior alveolar artery forms a broad groove in whose surroundings there are a number of minor perforations (Figure 8). An impression of one of the terminal branches of the artery shows a fine deposit of newly formed bone tissue.

On the internal side of the ventral third of one of the left-sided rib fragments, a lodgement of newly formed bone tissue with a length of about 24 mm, a height of 9 mm and a thickness of 0.1 mm is evident. An X-ray image shows a fracture line that only affects the inner layer of the compact bone tissue and a small portion of the spongiosa.

On the fragment of the first lumbar vertebra, there is evident asymmetry in the size of the upper articular processes, with the left process being about 3 mm lower than on the right side. Approximately in the middle of the left side of the vertebral body is a depression with a perforated bottom. An X-ray image shows an arcuate fracture line pointing to the centre of the spinal canal, indicating a healed compression fracture of the vertebral body.

At the distal end of the right humerus, ventromedially from the *epicondylus medialis*, there is a circular depression with a diameter of 6.7 mm and a depth of about 2 mm. The bottom of the depression

is porous, the edges are slightly prominent and rounded by the repair process. A similar but shallower depression is found in the area of the *sulcus nervi ulnaris* (diameter 5.1 mm, depth about 0.1 mm).

In the lateral part of the *facies poplitea* of the left femur, a thin layer of newly formed bone tissue is visible. The size of the defect is approximately 34 × 30.7 mm. The compact layer of bone remained intact.

DISCUSSION AND DIFFERENTIAL DIAGNOSTICS

Multiple pathological changes on the studied skeleton suggest that the affected individual suffered from an overall chronic disease or a combination of several pathological conditions.

Changes on the inner surface of the cranial vault in the form of atypical formation of imprints of the meningeal vessels, their rich bush-like branching, small granular impressions, pronounced hypertrophy of the diploe or fine periostotic plates of newly formed bone tissue can be caused by tumours, traumatic lesions, chronic tuberculous or other meningitis, anaemia, rickets, scurvy or other metabolic diseases (Lewis 2004).

TUMOURS

When evaluating lesions on the cranial vault, bone tumours seem to be the least likely, as tumorous osteolytic and hyperplastic lesions are of a somewhat different nature. Benign tumours (osteomas) are



FIGURE 6: The mandible fragment with a persistent milk second molar caused by agenesis of the second premolar (photo by Jana Vachová, X-ray by Martin Čuta).



FIGURE 7: Signs of chronic periodontitis at the edges of dental alveoli (photo by Jana Vachová).

usually solitary, of small size, well-defined and have the same structure as healthy compact or spongy bone tissue. Unlike in the individual studied, they do not cause changes in the imprints of meningeal arteries. Malignant tumours are characterised by considerable irregularities and bizarre shapes, with possible changes in the adjacent bloodstream, but can be distinguished by the absence of macroscopically clear traces after the repair process (Aufderheide *et al.* 1998, Ortner 2003, Strouhal, Němečková 2008)

TRAUMATIC LESIONS

Trauma may also be the cause of pathological changes in the skull of the studied skeleton. Head trauma could cause epidural bleeding from impaired meningeal arteries. The epidural haematoma would later ossify and cause a thickening of the cranial vault. Subsequent irritation of the leptomeninges could cause aseptic inflammation of the meninges, which could result in arborisation of the *sulci arteriosi*. Since pathological changes have also been reported on the postcranial skeleton, this diagnosis is unlikely. It could be a polytrauma. However, it is possible that traumatic lesions may have developed gradually, at different times. Since it was a young individual, injuries would occur in childhood. In this case, we can speculate that it could be pathological trauma, which occurred during normal physiological stress acting on the skeleton weakened by metabolic disease. In any case, the injuries are very well healed, even a compression fracture of the lumbar vertebra. This injury is most often caused by the action of a vertical force on the

vertebral body when falling from a height. Even today, it is considered a very serious condition that usually requires surgery due to the risk of spinal cord damage (Špaček *et al.* 1973). In this case, however, the preserved lower limb bones were not marked by the noticeable gracility that occurs due to inactivity in hemiparesis (paralysis). However, the lateral asymmetry of the upper articular processes of the affected vertebra (about 3 mm) suggests that compression in the left part of the vertebral body caused post-traumatic scoliosis of the spine. In the area of the thoracolumbar junction, the spine formed an arch with convexity on the right side. However, the afflicted individual probably would not have survived such a serious injury without proper treatment at the time.

Also, the appearance of symptoms of some dental diseases suggests a disease with metabolic disorder in childhood.

NONSPECIFIC OR TUBERCULOUS MENINGITIS

On the skeletal remains of the studied individual, some findings on the internal lamina of the flat bones of the cranial vault, could be evaluated as symptoms of chronic meningitis. According to the results of a number of palaeopathological studies (for example Jankauskas 1999, Santos, Roberts 2001), tuberculous meningitis is the most common cause of such lesions. Enamel hypoplasia also sometimes occurs in this chronic disease. However, as tuberculosis usually causes solitary lesions on the skeleton, multiple skeletal disorders, such as in presented case, does not match it. Also, the compression fracture of the vertebra was of quite a different character from that of spondylitis tuberculous. This type of fracture is most often caused by excessive vertical pressure on the spine in a fall from a height. Other pathological findings on the skeleton are also not typical of tuberculosis.

Chronic forms of meningitis may, in addition to tuberculosis, also be caused by some types of viruses. Even in these cases, the postcranial skeleton is not affected.

ANAEMIA

Some authors (e.g. Henschen 1961, Koganei 1912) consider intracranial lesions to be one of the manifestations of anaemia or other metabolic diseases with a similar aetiology as *cribra orbitalia* (Hengen 1971). Anaemia and metabolic disorders are not only stand-alone primary diseases, but they also originate

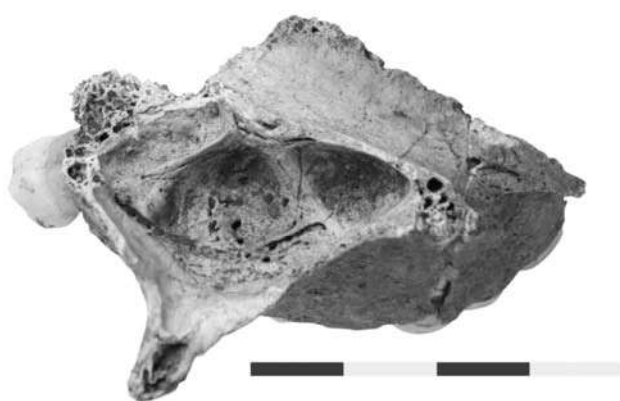


FIGURE 8: Pathological changes at the bottom of the right sinus maxillaris (sinusitis maxillaris). The posterior superior alveolar artery forms a broad groove in whose surroundings there are a number of minor perforations.

secondarily as one of the symptoms of other diseases, including scurvy. However, exclusion of anaemia in palaeopathology as a separate unit is very problematic (Zuckerman *et al.* 2014). Anaemia may not be a separate primary disease, but it is more likely to be one of the symptoms of a huge number of other diseases. Secondary anaemia may be associated with some endocrine or infectious diseases malignant processes, liver disease, etc.

SCURVY

After evaluating all the findings on individual bones, it can be assumed that they are symptoms of vitamin C deficiency – scurvy, but undergone in childhood. For this reason, some of the classic symptoms of childhood scurvy in the adult are remodelled by a repair process. Scurvy is manifested in a variety of changes on skeletons, the main cause of which is the failure of enchondral ossification and the occurrence of numerous subperiosteal haematomas. On the skull, porous, hypertrophic foci can be seen. Also the *sulci arteriosi* of the meningeal arteries are characterised by a rich branching. In the orbit, the usual findings are *cribra orbitalia*, possibly also conspicuous hyperostosis on their lateral walls. Porous lesions or lodgements of newly formed bone tissue on sphenoid bone or jaws may also be present. On the upper jaw, the plates of newly formed bone tissue are located mainly on the infratemporal surface of the body, on the palatal and alveolar processes or in the *sinus maxillaris*. The *processus coronoideus* and the medial area of the ramus are usually affected on the lower jaw. On the palate and alveolar processes, there may be signs of chronic inflammation of the periodontium, sometimes in the form of overdeveloped *torus mandibularis* and *maxillaris*. In severe cases, tooth loss is not an exception. On the postcranial skeleton, there may be traces of calcified subperiosteal haematomas in the form of lodgements of newly formed bone tissue. The same formations may be located on joint surfaces or in their proximity as a remnant of bleeding into joints – haemarthroses. However, subperiosteal haematomas may be resorbed instead of calcification, causing significant bone loss, particularly in the metaphysis area. Secondary stress fractures can occur at normal physiological load. In their healing, somewhat due to insufficient periosteal bone formation, a thinned cortical layer and sparse trabeculae appear at the callus site, which in the X-ray image resembles its "cut glass" structure. In severe cases, the whole skeleton is deossified, which leads to

a reduction in the momentum and overall bone atrophy of inactivity.

Based on the analysis of the ratio of isotopes of carbon ($^{13}\text{C}/^{12}\text{C}$) and nitrogen ($^{15}\text{N}/^{14}\text{N}$) from incisor ($\delta^{13}\text{C} = -20.07$; $\delta^{15}\text{N} = 12.35$) and based on teeth microabrasion (NV = 69, NH = XT = 163.3), it was found that the group of inhabitants of Podivín was mainly fed with meat, although farming already prevailed in the Czech lands at that time. In this context, it can be stated that meat, with the exception of the viscera, does not contain a sufficient amount of vitamin C. Isotope analysis covers the time period during tooth formation, while the microabrasion analysis captures the period of about half a year before the death of the analysed individual (Jarošová 2016, Nývltová Fišáková 2017)

Pathological changes on the studied skeleton in many aspects correspond to the diagnostic criteria of scurvy. The hypertrophy of the flat bones of the skull can be classified as a subperiosteal haematoma, or it may also be diploe hypertrophy in anaemia that occurs in scurvy due to bleeding. As response to mechanical irritation-inducing aseptic inflammation, the atypical formation of imprints of the meningeal vessels and the impression on the internal lamina of calvaria can be considered. Traces of periodontitis on the circumference of dental alveoli are typical in scurvy. It may also be related to hypoplasia of tooth enamel, according to which vitamin C deficiency can be estimated in childhood (3–4 years of age). As a result of connective tissue disorder, a left rib infraction and a compression fracture of the first lumbar vertebra could develop. The sign of haemarthrosis of the left knee joint may be the newly formed bone tissue on the *facies poplitea* of the left femur.

At this point, *recessus popliteus* communicating with the knee joint cavity can be formed. The traces after a degenerative process in the right elbow joint remain questionable. They originated apparently as a complication of soft tissue trauma. Palatoradicular grooves are hereditary defects of the dentition and are not related to the scurvy, while the persistence of the milk molars and the agenesis of the second premolars can be caused by this disease. The second premolars start to form only postnatally, usually around the first year of life. If the second premolars did not start to form due to vitamin C deficiency, the milky molars persist until adulthood. The end of the first year of life is also the age at which deficiency of dietary vitamins is most common when switching from breastfeeding to solid food. Therefore, it can be assumed that the

affected man suffered from scurvy as a small child between 1 and 4 years of age. In the next period of life, this food deficit was balanced and many symptoms disappeared into adulthood. This view is supported by Wapler *et al.* (2004), for example, who consider *cribra orbitalia* remodelling to be a significant sign of healing.

CONCLUSIONS

Pathological changes on the skeleton of an adult man dated to ca 3800–3700 BC (diploe hypertrophy of flat bones of the cranial vault; atypical formation of impressions of meningeal vessels and granular impression on the internal lamina of the calvaria; developmental dysplasia of the dentition – palato-radicular grooves on the second upper incisors, persistence of the second lower milk molars and agenesis of the second lower premolars – oligodontia; hypoplasia on frontal teeth crowns; chronic parodontitis; left side rib infarction; compression fracture of the body of the first lumbar vertebra, followed by scoliosis and asymmetry of the upper articular processes; circular depression in the course of the right *sulcus nervi ulnaris*; newly formed bone tissue on the *facies poplitea* of the left femur) are possible manifestations of scurvy. The affected individual probably suffered from this disease in childhood, therefore, some symptoms were remodelled when healing. The finding extends a piecemeal knowledge to this day of the occurrence of scurvy in the interior of Central Europe during the Eneolithic.

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