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A case of a large pedunculated-type osteochondroma from late medieval Ilok, eastern Croatia: Bioarchaeological, paleoradiological and histological study

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ABSTRACT

Osteochondroma or osteocartilaginous exostosis is one of the most common benign tumors of the bone. Causes for the disease are yet unknown, but there are indications that they may be linked to abnormality in the growth plate and possibly mutation in EXT1, EXT2 and EXT3 genes. Cases of reported osteochondromas range from prehistoric to contemporary examples, are not limited geographically, and no evidence for sex predominance has been reported.

Here we present a unique case of large pedunculated-type osteochondroma on the right fibula of an adult female skeleton from the medieval site of Ilok-Krstbajer in eastern Croatia. In order to gain more insight into this pathological change we used holistic approach consisting of a combination of techniques that have not been used previously in the analysis of neoplasms from archaeological settings.

The cauliflower-shaped growth is 50 mm long in sagittal and 57.41 mm in transverse diameter with the tumor exhibiting a bulbous, rough superior surface, and a flat, smoother inferior surface. The gross morphology of the tumor together with radiological and histopathological features support the diagnosis of a proximal fibular osteochondroma making it the first such case in an archaeological population. Based on archaeological context and similar clinical cases it seems that the presented osteochondroma did not have major impact on the life-quality of a woman affected by this pathology. The procedure used in this study is minimally invasive and highly accurate, and as such sets new analytical criteria for studies of ancient bone neoplasms.

1. Introduction

Osteochondroma, or cartilaginous exostosis, is one of the most common benign tumors of the growing bone, first described by Hunter in 1789 (Stieber et al., 2001), and later referred to as "*exostosis bursata*" by Orlow in 1891 (Orlow, 1891; also see Murphy and McKenzie, 2010; and references therein for an insight into various terms used for osteochondroma). It represents a cartilage-capped bone outgrowth that may be pedunculated or sessile in appearance (Helms, 2007). Osteochondromas mostly occur on metaphyseal surfaces of long bones such as femur and tibia and are almost completely absent from diaphyses and epiphyses; in very few cases they may appear on smaller tubular bones (Schajowicz, 1994; Ortner, 2003; Marques, 2019). The lesion's involved area, the inner layer of the periosteum, causes it to produce cartilage instead of bone, thus omitting the possibility of a cortex which would separate the medullary spaces of the exostosis from those of the affected bone (Ortner, 2003). While the tumor initially forms as a rounded outgrowth, its final shape is modified by mechanical stress; the exostoses around the knee area, for example, form into elongated polypoid structures with bulbous tips pointing outward as a result of secondary

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remodeling (Ortner, 2003). Whilst mostly asymptomatic, their presence is often noted due to their mass, which can cause compression on the surrounding nerves and blood vessels (Kitsoulis et al., 2008). Malignant transformation is extremely rare and the more axially situated lesions are more prone to undergo malignant degeneration (Klein et al., 2018). If the thickness of the chondral cap *in vivo* is more than 15 mm, malignant transformation can happen (Klein et al., 2018).

Osteochondromas are classified into two categories: solitary (non-hereditary) and multiple osteochondroma (mostly hereditary) (Jenifer et al., 2016). Causes for the disease are yet unknown, but there are some indications that they may be linked to abnormality in the growth plate and possibly mutation in EXT1 gene (for solitary osteochondroma) and mutations in EXT1, EXT2 and EXT3 genes (for multiple hereditary osteochondroma) (Gaetani et al., 1996; Bovée and Hogendoorn, 2008; Kitsoulis et al., 2008; Pannier and Legeai-Mallet, 2008). Cases of reported osteochondromas range from prehistoric times to recent examples (Chamberlain et al., 1992; Lyall and Mann, 1993), are not limited geographically (Murphy and McKenzie, 2010; and references therein), and no evidence for sex predominance has been observed (Stieber and Dormans, 2005).

In our study we aimed: (i) to present a unique case of a large pedunculated-type osteochondroma on the medio-posterior part of the right fibula from the medieval site of Ilok-Krstbajer in eastern Croatia, (ii) to verify our diagnosis by using multi- and interdisciplinary approach consisting of a combination of techniques that have not been used previously in the analysis of neoplasms from archaeological settings, (iii) to gain a better understanding of lived experience of this individual and to reconstruct possible impact the osteochondroma might have had on her every-day life.

2. Materials and methods

The archaeological site of Ilok-Krstbajer is located in the eastern part of the town of Ilok in eastern Croatia, on the right bank of the Danube River some 200 m from the present-day Croatian-Serbian border (Fig. 1). The site was partially destroyed during the exploitation of sand for construction purposes in 2011 (Krznar and Rimpf, 2018). In response to that, the Ilok Town Museum in cooperation with the Institute of Archaeology from Zagreb carried out a rescue archaeological excavation which was followed by three seasons of systematic excavations between 2015 and 2017 (Krznar and Rimpf, 2018). The excavated trenches covered approximately 84 m^2, and apart from several prehistoric layers some 188 medieval burials dated between the end of the 12th and the 15th/16th century CE were studied (Krznar and Rimpf, 2018). The burials probably belonged to the parish cemetery around the church of St. Helen the Queen (Krznar and Rimpf, 2018). Burial 176 contained a partially preserved skeleton of an adult individual (the cranium, the right arm and most of the feet bones were missing post-mortem) oriented east–west lying on its back with the left arm positioned on the pelvic region. The burial was positioned well within the perimeter of the cemetery and not on its edges while the position and depth of the burial as well as the skeleton were similar to all other contemporary features from the site. Large osteochondroma was visible on the proximal end of the right fibula even during the excavation (Fig. 2). A coin (silver denarius) of Louis I of Anjou (1342–1382) was found within the grave fill just left of the right femur (Supplementary Fig. 1). The obverse shows the bust of Louis I holding royal insignia - a scepter and a royal apple and the inscription REX LODOVICI, while the reverse shows Hungarian Anjou coat of arms and the inscription REGIS LODOVICI (Supplementary Fig. 2). According to Huszár (1979) the coin can be classified as type 532. The coin dates the use of the burial to the second half of the 14th and/or the early 15th century CE.

During the 14th century CE Ilok was a relatively wealthy market town due to viticulture, trade and various crafts (Andrić, 2001). In 1364, king Louis I gave the ownership over the town to Nicholas Kont and his nephew Ladislaus who added the title Iločki (de Wylak) to their family name (Andrić, 2001). The family and the town reached their peak during the Ladislaus' son Nicholas and grandson Lawrence (Andrić, 2001). Nicholas was a viceroy of Syrmia and was even crowned for the king of

Fig. 1. Map showing the geographic location of Ilok.

Fig. 2. Burial 176 *in situ*. The presented osteochondroma was visible even during the excavation (in red circle). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Bosnia in 1471. In 1453 king Ladislaus V of Hungary granted Ilok a status of free royal town (*civitas*). During the rule of Nicholas there was also a mint within the town limits (Horvat, 2002). Probably the most important historic document testifying on Ilok's importance during the Late Middle Ages is the Town's Statute dated to 1525 (for more details see Andrić, 2003). The town comprised of two distinct settlements - the Upper Town with a royal palace and the Lower Town. The Upper Town was located on the hills above the Danube River and it was completely fortified by massive walls and towers - it was a seat of royal and church authorities (Tomičić, 2003). The Lower Town (*suburbium*), located under the Upper Town, was a civilian settlement with a market place at the important Danube crossing (Tomičić, 2003). Based on the number and size of the seven churches located within the town limits during the 15th century Andrić (1996) suggested that Ilok could have had between 2100 and 2500 inhabitants. Detailed results of bioarchaeological studies of skeletal and dental remains of late medieval and post-medieval inhabitants of Ilok were published by Novak et al. (2017), and Rimpf and Novak (2020).

Conventional bioarchaeological analysis of the remains from burial 176 was conducted at the Laboratory for Evolutionary Anthropology and Bioarchaeology of the Institute for Anthropological Research in Zagreb. The biological sex of the studied individual was established based on the macroscopic examination focusing on the differences in pelvic morphology between adult males and females (Buikstra and Ubelaker, 1994; Bass, 1995; Klales, 2020). The age-at-death was estimated by using pubic symphysis (Brooks and Suchey, 1990), auricular surface morphology (Lovejoy et al., 1985; Buckberry and Chamberlain, 2002), and sternal rib end changes (Işcan et al., 1985). All available remains were examined macroscopically. Possible presence of various pathological changes usually seen in archaeological samples and all observed lesions were documented according to criteria described by Ortner (2003), and Aufderheide and Rodríguez-Martín (1998). The stature was reconstructed based on the maximum femoral length by using the formulae proposed by Trotter (1970).

The neoplasm in question was scanned on X-ray unit (Siemens) in AP and LL positions using 55 kV and 6 mAs and on Multislice computerized tomography (MDCT) unit Sensation 16 (Siemens Erlangen, Germany) with the following scan parameters: 16 × 0.75 mm, 130 KVP, and 160 mA with field of view 111 mm. Soft (30) and sharp (70) kernel algorithms were used to reconstruct images. Post-processing was done using imaging processing open source software Horos (Horos project, v3.2.1, www.horosproject.org).

The sample was scanned using a Skyscan 1076 micro-CT device (Bruker, Belgium) as well. Scanning was done at 70 kV and 140 μA, yielding an isotropic resolution of 18 μm. Due to the width and thickness of the bone sample aluminum filter of 1 mm thickness was used to prevent beam hardening. The rotational step was 0.6^{O} throughout 198^{O} with a frame averaging set at 2. Obtained images were reconstructed using NRecon software (Bruker, Belgium) by employing GPU-based reconstruction with merger of multiple fields of view (FOV) into one dataset. Scanned sample was visualized using CTVox software (Bruker, Belgium). For an advanced bone analysis CTAn (Bruker, Belgium) software was used. Osteochondroma was manually delineated and subsequent parameters were analyzed: bone volume (BV), trabecular pattern factor (Tb.Pf), structure model index (SMI) and degree of anisotropy (DA). For Ellipsoid Factor (EF) calculations, ImageJ/BoneJ software was used. Binarized images from micro-CT were imported and used as a template for EF calculations (Doube et al., 2010).

Sampling was done under CT guidance to minimize damage and to visualize the entrance point. Biopsy was done using Arrow® OnControl® Powered Bone Access System (Teleflex, USA). Guiding needle (11 G thick) was inserted inside the lesion (Supplementary Fig. 3), and after the position was confirmed on CT a sample was taken with a biopsy needle (13 G thick). Material was sent to histopathological analysis. After formalin fixation, careful decalcination in EDTA and paraffin embedding the slides were stained in HE and Mallory trichrome.

3. Results

The analyzed osteological material was relatively well preserved with some post-mortem cortical damage and fragmentation on some bones. The skeleton belongs to an adult female aged between 35 and 45 years at death, with a reconstructed height of 157.84 ± 3.72 cm. Several pathological lesions, mostly in the vertebral column have been observed - osteoarthrosis on L2, L3, L4 and L5 vertebrae, as well as Schmorl's nodes on T10-T12, L1 and L2 vertebrae.

The pedunculated-type of osteochondroma is present on the medio-posterior part of the right fibula; its superior surface starts 26.7 mm below the proximal articular surface of the fibula which is damaged post-mortem (Fig. 3A). The cauliflower-shaped growth is 50 mm long in sagittal and 57.41 mm in transverse diameter (Fig. 3B-C). The tumor exhibits a bulbous, uneven, rough superior surface (Fig. 4), and a flat, smoother inferior surface. A postmortem loss of a piece of the lesion is noted on its posterior part, at the tip of the tumor. Several similar smaller holes are scattered throughout its body. The tallest protrusion of the osteochondroma is situated superior to the mentioned missing piece. The observed trabecular bone within the mass densifies outward, along with the tumor's expansion. Two outgrowths—the smaller on the antero-lateral and the larger on the postero-medial side—are missing post-mortem. The latter outgrowth exhibits rectangular postmortem edges of lighter tan color, whilst its antero-lateral counterpart possesses two distinct oval/ellipsoid fracture edges of the same hue, with a cluster of five smaller tumors in between. X-ray showed pedunculated, well described mass without periosteal reaction or cortical disruption (Fig. 5).

Micro-CT scanning revealed that the osteochondroma is fully

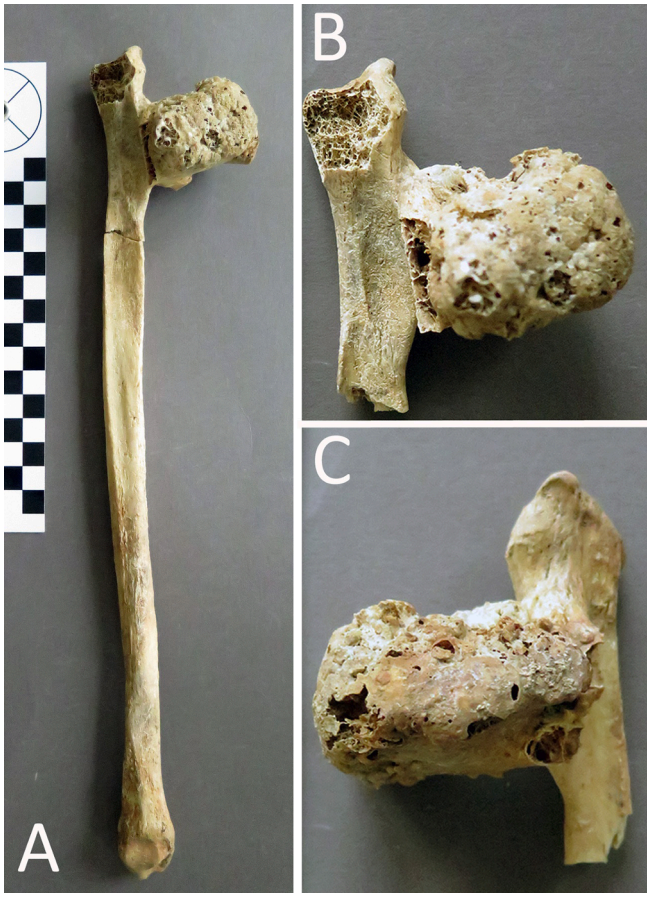

Fig. 3. The position of the osteochondroma on the medio-posterior part of the right proximal fibula (A). A detailed view of the osteochondroma in question: posterior (B) and anterior (C).

Fig. 4. A bulbous, uneven, rough surface of the superior part of the osteochondroma.

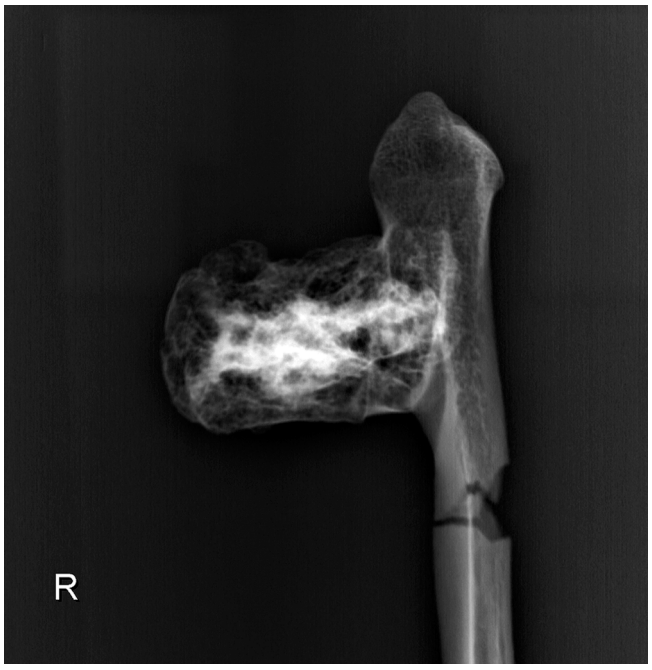

Fig. 5. X-ray image (A-P view) showing pedunculated, well described mass without periosteal reaction or cortical disruption.

integrated with the fibula, as the fibular cortical bone opens towards and anchors the osteochondroma (Fig. 6A). The formation of the trabecular bone within the medullary canal of the fibula, at the site of osteochondral anchoring, was observed and that points to congenital origin of the osteochondroma. Bone that comprises the osteochondroma is mostly trabecular bone with extensive plate-like structures in the center (Fig. 6B). Plate-like trabeculae are mechanically superior to rod-like trabeculae (Hildebrand et al., 1999) suggesting that osteochondroma was mechanically loaded and remodeled, and not just inactive, dormant bone mass. Quantitative micro-CT analysis of the fibular trabecular bone and osteochondroma (Table 1) showed that the total bone volume inside of fibula was only 1.7% of osteochondroma bone. Trabecular pattern factor (Tb.Pf), as a measure of trabecular connectivity, showed almost 100% increase in osteochondroma. Structure model index (SMI) and ellipsoid factor (EF), as measures of the trabecular plate-like or rod-like morphology, showed around 30% and 57% increase, respectively, towards plate-like morphology in osteochondroma. Similar values for degree of anisotropy (DA), show structured trabecular formation in both, trabecular bone and osteochondroma.

The determination of a possible malignant transformation was attempted via a histopathological examination. The obtained material consisted of tiny, partly dust-like bony or osteochondromatous fragments. In most of the fragments, lamellar or lamellar and woven bone is either surrounding mature cartilaginous tissue or there are areas of enchondral ossification (Fig. 7A). In some fragments, there is loss of structure, reminiscent of osteomalatia, mainly surrounded by woven (reactive) bone (Fig. 7B). In one fragment, the interrelation of bony, cartilaginous and malatic fragments shows a pattern of necrotic changes surrounded by reactive/reparatory bone (Fig. 7C). The histological features are consistent with a chondromatous lesion (enchondroma or osteochondroma) with reactive/reparatory changes indicating a trauma relatively short ante-mortem (or recurring/chronic, due to collision with surrounding tissue). No elements of malignant growth were registered.

4. Discussion

Today, osteochondromas represent the most common benign bone tumor accounting for 20–50% of benign bone tumors and about 9% of all bone tumors (Brien et al., 1999; Murphey et al., 2000; Garcia et al., 2011). In the presented case it is evident that the tumor had predominantly benign characteristics as no aggressive destruction of cortical bone or periosteal reaction was noted. The study showed the full integration of the osteochondroma with the fibula and the trabecular bone formation within the medullary cavity points to a congenital origin of the pathology. Whatever the etiology of osteochondroma (it is generally accepted to be a developmental anomaly), its solitary instances are usually present in the form of slow-growing masses (Kumar et al., 2014). However, in order to make an accurate diagnosis we have to take some other benign tumors in consideration. Since the most common types of benign primary tumors appearing in the fibula apart from osteochondromas are enchondromas, aneurysmal bone cysts and non-ossifying fibromas (Arikan et al., 2018; Gümüştaş et al., 2021) these three were taken into consideration for differential diagnosis. Enchondromas are cartilaginous tumours that may be single or multiple. The single tumours occur most frequently in the hands, mostly in the proximal phalanges with a distinct preference for the fifth ray of the hand (Gaulke, 2002). The localization of this neoplasm in Jaffe's (1958) review, from the most to the least frequent location, was as follows: finger phalanges, metacarpals, humerus, femur, toe phalanges, metatarsals, tibia, fibula, and ulna. The radiological appearance of enchondroma is characteristic with the lesion appearing intramedullary, well defined with a lobulated appearance and endosteal erosion (Waldron, 2009). Aneurysmal bone cysts are blood-filled cysts which appear as a distinct bulge consisting of a thin newly formed shell over the eroded cortex (Leithner et al., 1999; Ortner, 2003). The lesion occurs with equal frequency in long bones and in the spine. In long bones, the location is usually the metaphysis, seldom the diaphysis (Ortner, 2003). Radiologically it appears as an eccentric lytic area, often with trabeculation, the inner surface of which is generally well defined and there may or may not be a sclerotic rim. The cortex is thinned and appears to be ballooned and periosteal new bone is often present (Mankin et al., 2005). And finally, non-ossifying fibroma consists of connective tissue cells and usually appears in the long bones in children, most often the femur (Caffey, 1955). This neoplastic lesion derives from a fibrous cortical defect that behaves aggressively and continues to grow; it always starts eccentrically in the metaphysis of long bones and, even after penetration into the medullary portion of the bone, is separated from the medullary tissue by a distinct, frequently scalloped, bony shell (Ortner, 2003). They appear as small defects in the distal shaft of one of the long bones with a sclerotic margin on X-ray and they may be multiple (Blau et al., 1988). When these data

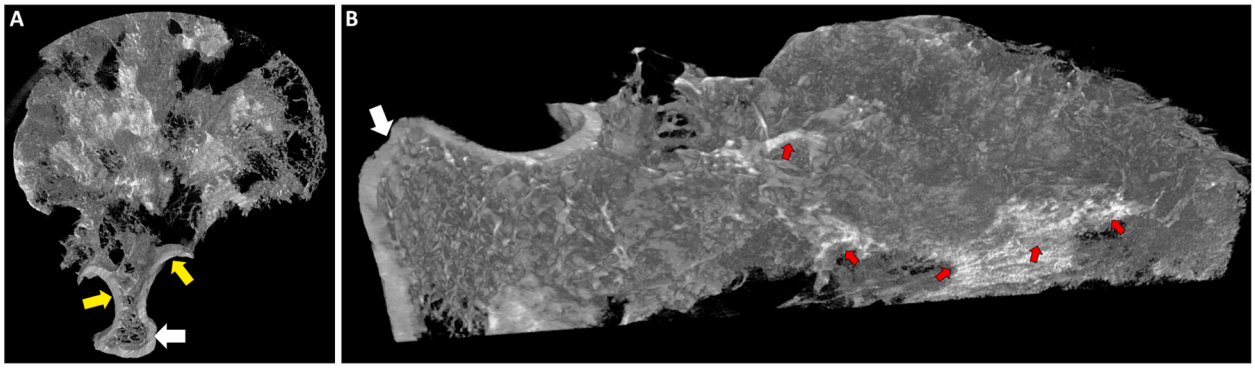

Fig. 6. Visualization of the osteochondroma by micro-CT. Integration of the osteochondroma (yellow arrows) with the fibula (white arrow) indicates congenital origin (A). Trabecular bone in the medullary canal of the fibula (white arrow) and large plate-like structures in the osteochondroma (red arrows) are shown (B). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Osteochondroma quantitative parameters calculated by micro-CT analysis. Osteochondroma trabecular bone was compared to trabecular bone in the medullary canal of the fibula.

Trabecular bone	Bone volume/BV (mm^3)	Trabecular pattern factor/Tb.Pf (mm^{-1})	Degree of anisotropy/DA	Structure model index/SMI	Ellipsoid factor/EF
Osteochondroma	7769.7	2.4955	1.3199	1.5209	0.0166
Fibula	132.9	4.9297	1.3010	1.9812	0.0260

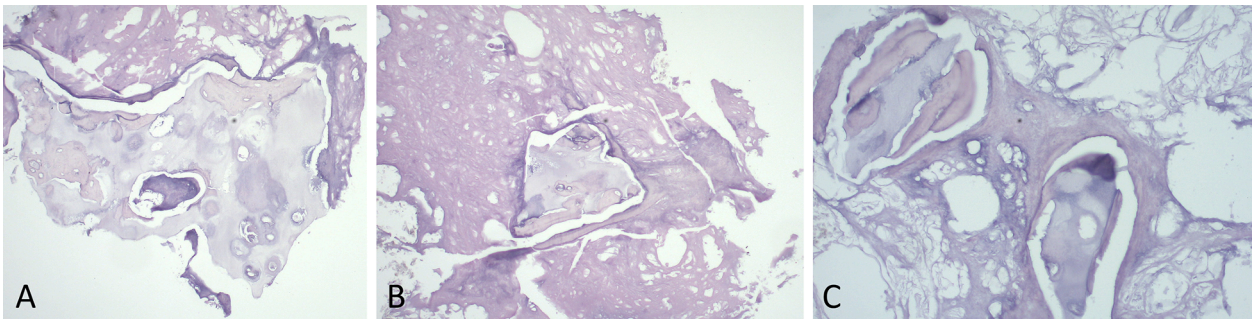

Fig. 7. Lamellar bone surrounding mature cartilaginous tissue/areas of enchondral ossification (A). A fragment with a loss of structure, surrounded by woven (reactive) bone (B). Necrotic changes surrounded by reactive/reparatory bone (C). HE staining after formalin fixation, EDTA decalcination and paraffin embedding. Objective x10. HD CCD camera.

are taken into consideration it is clear that both macroscopic and radiological appearance as well as localization of the presented case rule out the possibility of enchondroma, aneurysmal bone cyst and/or non-ossifying fibroma, and point out to osteochondroma as the main "suspect".

In order to additionally confirm our diagnosis and to get a better insight into the internal microstructure of the lesion in question we used micro-CT imaging. Bone tissue is an optimized structure that has a maintained geometry as a response to hormonal status and mechanical loading (Wolff, 1893). Pathological changes can change bone tissue equilibrium and cause the disruption of structure optimization. To analyze osteochondroma geometry we compared its trabecular bone with trabecular bone within the fibula. Morphological parameters are indispensable for trabecular microstructure characterization during remodeling processes and thus we used the parameters that describe the geometry and biomechanical strength. Extensive analysis showed that bone volume normalized by tissue volume (BV/TV) and bone anisotropy are the best variables to describe the elastic behavior of trabecular bone (Maquer et al., 2015). Our results showed that, although BV was much higher in osteochondroma, the anisotropy was quite similar in both structures indicating that osteochondroma was mechanically loaded and relevant structure for posture and movement. The connectivity of the trabeculae was depicted by the use of trabecular pattern factor (Tb.Pf). Since osteochondroma had much greater BV, consisting almost exclusively of trabecular bone, the increase in trabecular connectivity was expected. To further discern the trabecular geometry, we analyzed the shape of the trabeculae in both samples. Rod-like and plate-like shape of the trabeculae also determine their strength, where plate-like trabeculae are stronger (Staube et al., 2006). The most commonly used parameter for determining trabecular geometry is structure model index (Hildebrand and Rüegsegger, 1997). Recently, research showed that SMI is strongly influenced by BV/TV and does not properly address real bone structures (Salmon et al., 2015). Instead, authors propose ellipsoid factor as the more accurate parameter for trabecular geometry characterization (Doube, 2015). We have analyzed both parameters and have shown that SMI and EF are steered toward stronger, plate-like, geometry in the osteochondroma when compared to fibular trabecular bone. With all this in mind, we are certain that the osteochondroma, although a heterotopically generated bony mass, was mechanically loaded and was remodeled throughout the life of this person.

Certain benign tumors have the potential to become malignant (Hesketh, 2013). For example, enchondroma can progress to a malignant chondrosarcoma (Garrison et al., 1982). For that reason we wanted to exclude the malignant transformation and decided to use "minimally" invasive technique and to take a sample of a tumor to confirm the diagnosis histologically. The techniques such as CT-guided biopsy are

used in radiology routinely in clinical settings, but in paleoradiology these methods are still under-used (e.g. Rühli et al., 2002; Čavka et al., 2012). As a result, histopathological analysis found only traces of reactive and reparatory changes with histological features consistent with a chondromatous lesion (enchondroma or osteochondroma) and without any elements of malignant growth. In this context we can offer a diagnosis of osteochondroma based on pathological-radiological correlation with a high degree of certainty.

Cases of osteochondroma in archaeological populations have been reported by many authors regardless of chronological and geographic contexts (e.g. Vyhnánek et al., 1999; Šlaus et al., 2000; Buzon, 2005; Murphy and McKenzie, 2010; Antunes-Ferreira et al., 2014; Nicosia et al., 2016; Isidro et al., 2017; Varotto et al., 2020) with the chronologically oldest known case being of a juvenile female from Neolithic England (Chamberlain et al., 1992) (for a general review of benign bone tumors in bioarchaeology see Siek, 2020). The fibular osteochondroma presented in this paper is only the second case of osteochondroma registered in archaeological populations from Croatia, but also from Central/Southeastern Europe. So far, the only known similar specimen from the region was registered in the early medieval (11th century CE) site of Lobor in NW Croatia - this is the case of cauliflower-like osteochondroma located on the anterior side of the neck of the right femur of a middle-aged male (Šlaus et al., 2000). Although the locations of these two osteochondromas are not similar they share an almost identical morphology and structure. Besides being the only second documented case of osteochondroma from archaeological contexts from the region, the medieval case from Ilok is the first ancient documented specimen of a large fibular osteochondroma globally, at least to the available literature. Considering the fact that only 2.5% of primary bone tumors are located in the fibula (Unni and Inwards, 2010), and that the majority of osteochondromas appear on the metaphyseal surfaces of long bones—most often on the femur and tibia—and are rarely found on smaller tubular bones (Schajowicz, 1994), this makes the case of a fibula-based osteochondroma from Ilok of an even greater interest.

Since one of the main aims of this study was to gain a better understanding of lived experience of the medieval female from Ilok, we need to discuss the archaeological and social context of her burial. So far, several approaches have been proposed and successfully used in similar studies from various bioarchaeological contexts (e.g. Knüsel et al., 2010; Tilley and Cameron, 2014; Marklein et al., 2016). Although we don't have much data when looking at the mortuary aspect it seems that this individual was not treated differently from other members of her community. As already mentioned, the position of the burial (well within the cemetery at the similar depth as other contemporaneous burials) as well as the position and treatment of the skeleton (east–west orientation, arm(s) on the pelvic region which was the norm at the time) suggest that she was considered a full member of the community and was buried with all honors as other citizens of late medieval Ilok. The addition of a silver coin in the grave fill might suggest that she (or at least those who buried her) was rich enough to afford such an act (possibly craftsperson or a trader) indicating a somewhat elevated social status. And finally, the question is whether this individual suffered any lasting effects in terms of mobility and while conducting daily activities due to the observed osteochondroma, i.e. if she needed care or help from other members of her family and community? Several clinical studies showed that fibular osteochondroma may result in pain without the restriction of the movement in the knee joint and/or neurovascular deficit in the extremity (e.g. Kumar et al., 2014). However, in more serious cases these may distort the normal anatomical course of nerves and vessels and it may lead to vascular compression syndromes and a pseudoaneurysm or peroneal nerve paralysis (Andrikopoulos et al., 2003; Mnif et al., 2009; Holzapfel et al., 2011). However, based on similar, and even more pronounced specimens such as the one presented by Kumar and colleagues (2014) it is possible (and even probable) that the woman from Ilok did not suffer from any major limitations in terms of mobility and conducting every-day chores, apart from visible swelling and possibly some pain. Although at this stage we do not have enough information it seems that the presented osteochondroma did not have major impact on her life-quality. Consequently, it seems that she did not require assistance and help from close kin and that she was regarded as a "normal" and functioning member of a community.

5. Conclusion

In our analysis we used a combination of conventional bioarchaeological methods and X-ray and micro-CT scanning together with CT-guided biopsy and histopathology to analyze the first case of a large fibular osteochondroma from archaeological contexts globally. Based on archaeological context and similar clinical cases it seems that the presented osteochondroma did not have major impact on the life-quality of a woman from medieval Ilok. This specimen is also the first case, at least to our knowledge, of confirmed diagnosis of ancient osteochondroma with an image guided biopsy. CT-guided biopsy minimizes the damage of surrounding structures, it enables the penetration in the center of the lesion and it helps in visualization of needle path afterwards. Therefore, considering the minimal invasiveness nature of the procedure, it may set new analytical criteria for studies of ancient bone neoplasms and it strongly advocates the further translation of CT-guided biopsies from clinical radiology into paleoradiology and (bio)archaeology.

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CRediT authorship contribution statement

Mislav Čavka: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. **Igor Erjavec:** Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Sven Seiwerth:** Formal analysis, Investigation, Methodology, Writing – review & editing. **Mario Carić:** Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Ivor Janković:** Writing – original draft, Writing – review & editing. **Siniša Krznar:** Resources, Writing – review & editing. **Andrea Rimpf:** Resources, Writing – review & editing. **Hrvoje Brkić:** Funding acquisition, Writing – review & editing. **Ivana Savić Pavičin:** Funding acquisition, Writing – review & editing. **Marin Vodanović:** Funding acquisition, Writing – review & editing. **Mario Novak:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2022.103574.

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