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SOMETHING OLD, SOMETHING NEW: (RE)ANALYSIS AND INTERPRETATION OF THREE BRONZE AGE TREPANATIONS FROM CROATIA

ABSTRACT: In this paper we present three prehistoric cases (two previously reported and one recently discovered) of trepanation from Croatia: Rudine, Bezdanjača and Jagodnjak, all dated to the Bronze Age. By using a detailed macroscopic analysis as well as radiographic imaging (x-ray and CT scanning) of the skulls, we provide a new assessment and interpretation for this type of surgical intervention during the Bronze Age. The first case was that of an adult male from the Rudine site dated to the Early Bronze Age; the second trepanation was recorded on an adult female from the Bezdanjača Cave, dated to the Middle/Late Bronze Age; the third case was observed on a juvenile cranium from the Jagodnjak site, dated to the Middle Bronze Age. All three cases exhibit several similarities: (i) all are located on the right side of the frontal bone; (ii) all three are of similar dimension/shape; (iii) in all cases all three layers of calvarium *were breached; and (iv) similar techniques for the trepanation procedure were used in all cases. These three crania represent the oldest cases of intentional medical interventions in the territory of modern-day Croatia, while the Jagodnjak individual is the youngest person thus far discovered with this kind of treatment in the region.*

KEY WORDS: Paleopathology – Prehistory – Surgical intervention – Cranium

INTRODUCTION

Trepanation is probably one of the most fascinating and well-studied intentional medical practices seen in human skeletal remains. Its origins are unclear, and the debate about whether the practice was completed for religious/ritualistic, medical, or both purposes continues to this day. Arnott, however, points out that the genesis of such and similar healing-related procedures in all ancient societies were most probably the same – they began as ritual acts, which people learned through experience were survivable,

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subsequently leading to their refinement and continued medical use.

Greek physician Hippocrates (ca. 460 - ca. 370 BCE), often called the "Father of Medicine", described particular types of cranial fractures that required surgical intervention. Trepanations are discussed in the works titled the "Hippocratic Collection", more specifically in "Places in man" and "On head wounds" (Gross 2003) that were possibly compiled and written after Hippocrates' death. Those texts were also the earliest written records of the procedure as well as of the instruments applied (Graham 2003), yet without written corroborative textual records documenting the way in which such instruments were used is based solely on speculation (Arnott 1997). Galen, the Roman/Greek physician from the 2nd and 3rd century CE, argued that trepanation was necessary for the relief of intracranial pressure in some skull fracture cases (Rocca 2003). Based on historical documentation, epilepsy, mental disease, and even melancholy were cited as reasons for the intervention (Gross 2003: 313–314). On that note, Lisowski (1967) proposed three particular groups of reasons for trepanation: (i) therapeutic, for the relief of cerebral pressure and treatment of head injuries; (ii) therapeutic/magic, for the treatment of headaches, neuralgia, or epilepsy (which may have been viewed as a type of evil spirit possession); and (iii) magic/ritual, for obtaining *rondelles* (round bone discs cut from the trepanation aperture with a perforated hole in the centre for suspension) post-mortem.

There are four methods for trepanation identified (Aufderheide, Rodríguez-Martín 1998): (i) scraping, in which a sharp-edged tool is repeatedly abraded over the designated portion of the bone until the cranial vault bone wears away and an oval or round-shaped perforation is created with broad, shallow-bevelled edges; (ii) incising, in which a pointed instrument inscribes into the bone creating an oval or round-shaped groove until completely penetrating both tables, with smooth, steeply-bevelled edges; (iii) linear grooving, in which a sharp-edged tool is applied perpendicular to the cranial vault surface and moved back and forth until a linear groove penetrates the skull–four such grooves (two overlapping parallel lines) in total are necessary to produce a rectangular shape; and (iv) joining adjacent burr holes, in which a series of small holes were drilled in a circle penetrating the cranial vault, the bridges subsequently broken, and the enclosing bone removed.

Even though trepanation should not have been particularly painful once the scalp and soft tissue have been breached (López *et al.* 2011) since neither bone (except the periosteum) nor brain possess pain receptors (Hong *et al.* 2010), there have been suggestions that anaesthesia in the form of sleep could have been induced before the procedure through consummation of sufficient quantities of alcohol and/or other narcotics (Keller 1966, Rose 2003). In Europe, the Neolithic peoples had known of the analgesic property of poppy flowers (*Papaver somniferum*), while nightshade mushrooms were also most probably used in the medieval period (Prioreschi 2003, Sabatowski *et al.* 2004). In the Balkans where the tradition of trepanation continued well into the 20th century, ethnographic texts tell of strong spirits (*rakija*) being consumed as anaesthetics (Barjaktarović 1948, Trojanović 1900).

The various types of instruments were used in prehistoric trepanning (blades, scrappers, drills, etc.) depending on method, but the transition from stone to metal tools over time may have impacted survival of the patient. At first, trepanations were performed using "instruments" or rather regular tools made of stone (such as obsidian or flint), as it was probably the most accessible (and in many cases, only) material. They were sterilized through knapping, as the removal of flakes to sharpen the edge removed potentially infectious adhering materials (Löwen 1997), since the lithic core inside the tool was sterile, having never before been exposed to air and microbacteria. Later metal instruments were simply washed after use, although water could have served as a potential carrier of bacteria (López *et al.* 2011).

According to some authors, the procedures with stone instruments were likely much shorter and apertures much smaller (Kirkup 2006, Piek *et al.* 1999, Stewart 1958). The reason for smaller dimensions of the defects may have been the reduction of blood loss during operation, especially if performed quickly (Weber, Wahl 2006). They were mostly circular in shape and less than 40 to 50 mm in diameter (Campillo 1984, Jordanov *et al.* 1988, Piek *et al.* 1999, Stone, Miles 1990, Weber, Czarnetzki 2001, Weber, Wahl 2006). Rates of infection after trepanation operations during the prehistory appear low based on inferences of survival from other published cases (Froeschner 1992, Marino, Gonzales-Portillo 2000, Piek *et al.* 1999, Stone, Miles 1990, Velasco-Suarez *et al.* 1992).

Successful trepanations are identified in skeletal material in the form of the smoothing of edges of cut bone surfaces (Capasso *et al.* 2002, Gerszten *et al.*

1998, Powell 1970, Jorgensen 1988, Rifkinson-Mann 1988, Stone, Miles 1990, Weber, Wahl 2006). While the first signs of osseous remodelling and regeneration may appear within the first week following the trepanation reflecting short term healing, the extent of recovery depends both on the individual and the size of the perforated aperture. In most cases, significant remodelling along the edges of apertures only develop over years after long-term survival (László 2014), while larger trepanations may never close completely. Children may exhibit faster regeneration due to higher metabolism rates. In any case, if such changes in the bone are not visible even with magnification, the trepanation is regarded as fatal, immediately or shortly following the surgery (Weber, Wahl 2006). These parameters were used in calculating the survival rates across different cultures and prehistoric times, and the results (ranging from 50 to 90% of healed openings) show correspondence with low infection rates, thus further cementing the high survival probability of those patients (Gerszten *et al.* 1998, Piek *et al.* 1999, Stone, Miles 1990, Velasco-Suarez *et al.* 1992, Weber, Czarnetzki 2001, Weber, Wahl 2006). It was not determined whether death in the remaining cases resulted from surgery (if the *dura mater* was breached and death was immediate due to exsanguination or direct infection) or some underlying disease (e.g. head injury, abdominal injuries, or pneumonia) (Weber, Wahl 2006).

In Croatia, there are eight documented cases of trepanations so far: one from the Early Bronze Age Cetina culture from the site of Rudine in the Dalmatian hinterland (Marović 1990, Mikić 1986); one from the Middle/Late Bronze Age Vrčin hillfort in Istria (Cupitò *et al.* 2018); one from the Middle/Late Bronze Age Bezdanjača site (Malez, Nikolić 1975) in the region of Lika; one from the town of Ludbreg dated to the Migration period (Novak *et al.* 2013); a skull from the Avar period cemetery of Nuštar dated to 8th/9th century CE (Premužić *et al.* 2016); a case of mastoid trepanation from the 11th century CE cemetery of Zvonimirovo (Boljunčić *et al.* 2015); one from the Late Medieval/Early Modern Age site of Škabrnja-Sveta Marija (Bedić *et al.* 2016); and one from the Early Modern Age site Pakoštane-Crkvina (Bedić *et al.* 2016) (*Figure 1; Table 1*). The case from Jagodnjak presented in this paper for the first time represents the ninth known case of trepanation from Croatia.

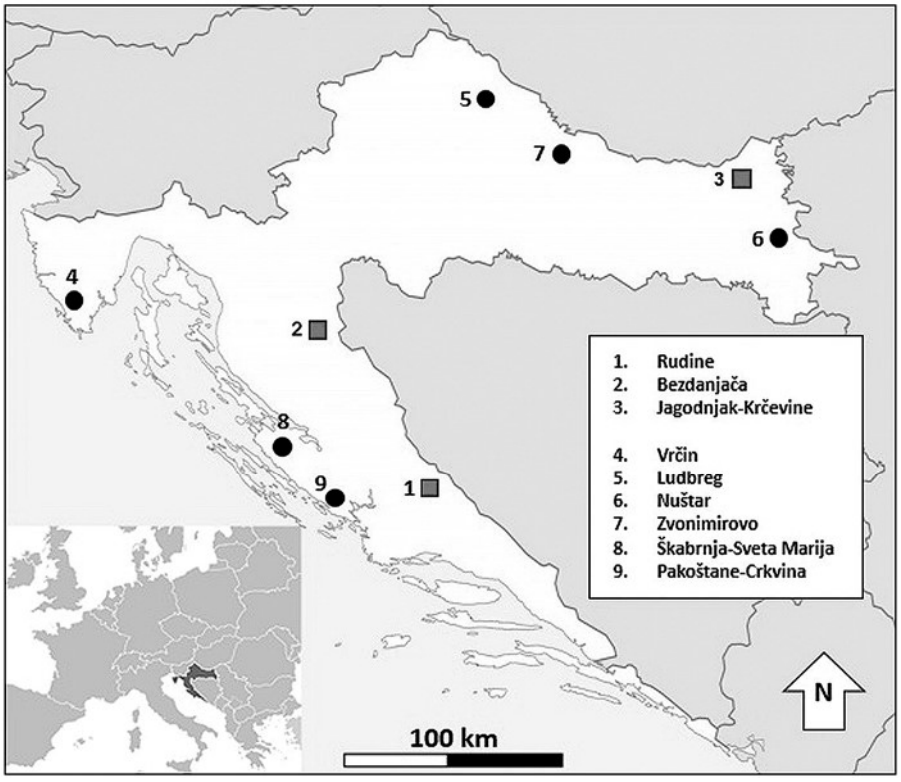

FIGURE 1: The archaeological sites with trepanation cases from Croatia (map by M. Carić).

TABLE 1: The overview of the known prehistoric and historic cases of trepanation from Croatia. [1] Marović 1990, Mikić 1986, presented here;[2] presented here;[3] Cupitò *et al.* 2018; [4] Malez, Nikolić 1975, presented here; [5] Novak *et al.* 2013; [6] Premužić *et al.* 2016;[7] Boljunčić *et al.* 2015; [8, 9] Bedić *et al.* 2016.

Site	Sex/age (yrs)	Chronology	Trepanation location
Rudine[1]	M, 35–45	Early Bronze Age	Frontal bone
Jagodnjak-Krčevine[2]	S, 11–13	Middle Bronze Age	Frontal bone
Vrčin[3]	F?, -40	Middle/Late Bronze Age	Right parietal bone
Bezdanjača[4]	F, 20–30	Middle/Late Bronze Age	Frontal bone
Ludbreg[5]	M, 51–55	Early Medieval Period	Frontal and left parietal bone
Nuštar[6]	M, 50+	Early Medieval Period	Left parietal bone
Zvonimirovo[7]	M, 30–34	High Medieval Period	Right mastoid
Škabrnja-Sv. Marija[8]	M, 40–55	Late Medieval/Early Modern	Frontal bone
Pakoštane-Crkvina[9]	M, 40–60	Early Modern Period	Right parietal bone

In this paper, we re-analyse two already known Bronze Age trepanations from Croatia (Rudine and Bezdanjača) by using conventional bioarchaeological approach together with x-ray and CT imaging. Based on the available literature and the newly acquired data, we propose new interpretations for these two cases. Special attention was given to the (re)analysis of the trepanation methods applied to the individuals in terms of marks and striations, the dimensions of the apertures, as well as their anatomical positions in relation to each other. Furthermore, we compare these trepanations with a new, previously unpublished, case of trepanation from the Middle Bronze Age site of Jagodnjak, the first case of child trepanation in the region. The new Bronze Age case presented here offers a suitable opportunity for the reassessment of older cases from the same period. Jointly, these three skulls (together with one from Vrčin that was unavailable for study) represent the earliest cases of this type of medical intervention in the territory of modern-day Croatia.

MATERIALS AND METHODS

Conventional bioarchaeological analysis of all presented remains was conducted at the Laboratory for Evolutionary Anthropology and Bioarchaeology of the Institute for Anthropological Research in Zagreb. This included sex and age assessment as well as palaeopathological analysis. Considering that only skulls were preserved in the case of Bezdanjača and Rudine, the sex assessment was based on the methodology and scoring systems described in Buikstra and Ubelaker (1994) and concentrated on nuchal, mastoid and supraorbital regions, glabella, mental eminence, and on the overall robusticity of specimens. Age-at-death for adults was determined based on cranial suture closure and dental attrition scoring systems described in Brothwell (1981) and Meindl and Lovejoy (1985). Taking into account that the individual from Jagodnjak is a subadult we did not try to estimate sex. The age of this individual was estimated based on the changes occurring during the development and formation of deciduous and permanent teeth (AlQahtani *et al.* 2009, Gustafson, Koch 1974, Moorrees *et al.* 1963a, b), the degree of long bone epiphyseal ossification (Scheuer, Black 2000), and the diaphyseal length of long bones (Maresh 1970).

Radiographic imaging of the skulls was performed at the Department of Diagnostic and Interventional Radiology of the University Hospital Centre Zagreb. X-ray and CT scanning were done utilizing a Multidetector computerized tomography (MDCT) unit (Emotion 16, Siemens AG Medical Solutions). Volume rendering technique (VRT) and 3D multiplanar reconstructions (MPR) were performed using Horos 3.3.5, open source medical image viewer.

The first re-analysed trepanation case comes from the site of Rudine, located in the Dalmatian hinterland, which consists of about one hundred burial mounds, and has been defined as part of the Early Bronze Age Cetina culture, dated to the second half of the third millennium BCE (Forenbaher 2018). The excavations at the Rudine site were led by I. Marović from the Archaeological Museum Split in 1958 and 1966 (Marović 1990, Mikić 1986). The trepanned individual

was discovered during the 1958 excavation (Marović 1990, Mikić 1986). Unfortunately, only the cranium was collected and available for the analysis. Due to inconsistent documentation during field work, a mix-up in data transcription occurred between Marović who excavated the site and Mikić who analysed the remains. Due to this fact, it is not possible to determine with certainty from which mound and burial this cranium originates - it was found either in mound 19/burial 1 or in a single burial from mound 21. Although the exact provenience of the trepanned skull is problematic, both burials are securely dated to the Bronze Age according to recovered artefacts and stratigraphy.

The second re-analysed skull comes from the Bezdanjača Cave, dated to the middle of the second millennium BCE (Middle/Late Bronze Age) based on associated pottery, metal findings, and several radiocarbon dates of the preserved wooden objects (Drechsler-Bižić 1979, Malez, Nikolić 1975, Sliepčević, Srdoč 1980). The site was excavated by M. Malez from the Yugoslav Academy of Sciences and Arts in 1965 (now Croatian Academy of Sciences and Arts), and the unearthed materials were published in the following decade (Drechsler-Bižić 1979, Malez, Nikolić 1975). The eastern or main shaft of the cave served as a cemetery, and is one of the largest known in Europe, with over 250 burials containing skeletal remains, thus enabling highly detailed anthropological analyses (Malez, Nikolić 1975). The faunal finds belong to the Holocene period, and consist mostly of wild and domesticated animals, which would indicate that the people interred in the cave were predominantly farmers and hunters (Malez, Nikolić 1975). Human skeletal remains were collected only partially (mostly skulls), and most of the assemblage is still located in the cave. Unfortunately, the cave itself is inaccessible at the moment due to mines left from the war in the 1990's. Malez and Nikolić (1975) reported that the trepanned skull—the only retrieved part of the skeleton — was part of a mass interment of over 30 individuals of varying ages and both sexes. The skeleton remains were commingled and disarticulated post-mortem. Apart from a few tiny pieces of pottery, no burial goods were found. The skull was discovered at the deepest part of the left shaft, which branches off from the main hallway.

FIGURE 2: Subadult skeleton with trepanation from Jagodnjak (burial 34) (photo by D. Tresić Pavičić).

The newest case of trepanation presented in this paper was found during rescue excavations led by D. Tresić Pavičić from Kaducej Ltd. in 2014/2015 at the site of Jagodnjak-Krčevine, located in eastern Croatia, some 25 kilometres north of the city of Osijek. The necropolis – which exhibits two distinct mortuary practices, inhumation and incineration – was part of the Middle Bronze Age Encrusted Pottery culture, dated to the first half of the second millennium BCE (Kiss *et al.* 2015). The trepanation was identified on the cranium of an individual from burial 34 who was lying on its left side with the legs in a contracted position (*Figure 2*). Besides the human remains, the burial contained faunal remains (animal bones, snails), several ceramic vessels as well as various metal objects made of bronze. The human skeleton was completely preserved with only some smaller bones missing. However, there was some cortical damage due to post-mortem erosion and weathering. Green stains resulting from metal oxidation were recorded on the left shoulder, the left ribs, and the right forearm.

RESULTS

The cranium from Rudine is only partially preserved: the posterior part of the frontal bone, the right parietal bone, a part of the left parietal bone along the sagittal suture, the right temporal bone, and the occipital bone. The skull belongs to an adult male of about 35 to 45 years at the time of death. Macroscopic analysis revealed an oval-shaped aperture on the right side of the frontal bone, three millimetres anterior of the coronal suture. The dimensions of the trepanation on the ectocranial side are 20 × 14 mm, and 10 × 8 mm on the endocranial side. All three layers of the *calvarium* were breached, and *dura mater* was most certainly exposed (*Figures 3a, b*). The slope is bevelled inward, with a more pronounced incline on the lateral side (*Figure 4*). There is evidence of bone remodelling around the edges, which can be clearly observed on CT images. A barely noticeable trace of inflammatory response is present in the form of remodelled porosity on the ectocranial side of the aperture. On the endocranial surface, the striations caused by scraping are clearly present, which may indicate that while healing certainly did take place based on the aforementioned observations, the existence of the marks themselves would suggest only short term healing (perhaps up to several weeks) since long term healing would have obliterated the tool marks. No other pathological changes have been observed on this cranium.

The Bezdanjača cranium is completely preserved, except a rectangular defect with dimensions 5×5 cm located posterior to the coronal suture on both parietal bones. The roughness of the edges and their light colour indicate post-mortem origin of this lesion, most probably caused by a rock fall. This skull belongs to an adult female of about 20 to 30 years of age. An oval-shaped aperture with dimensions of 13 × 10 mm is located three millimetres anterior of the coronal suture, on the right side of the frontal bone (*Figure 5*). The edges of the lesion are smooth with evidence of bone

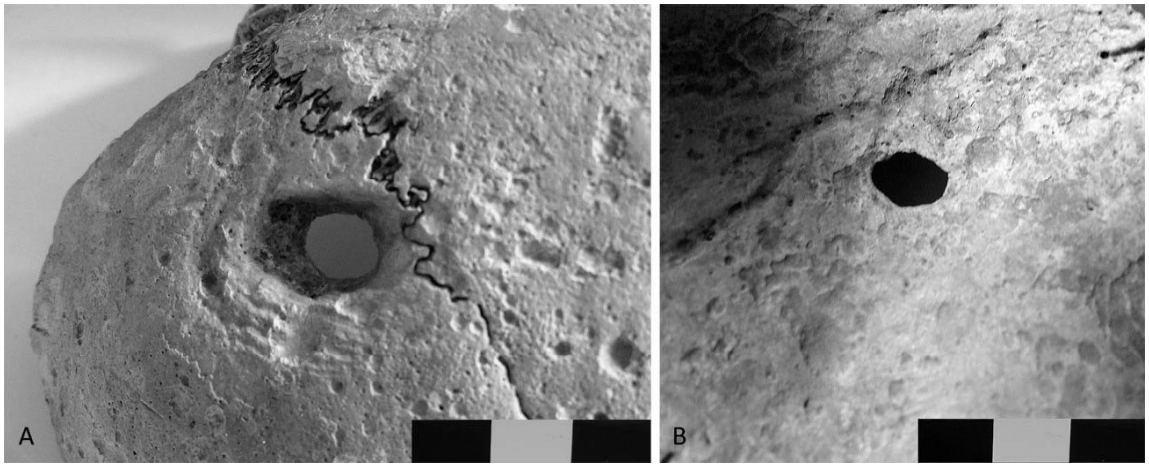

FIGURE 3: The trepanation from Rudine: a) ectocranial view; b) endocranial view (photo by M. Carić).

remodelling. On the endocranial side, a bone *rondelle* 1 mm thick is fused with the medial edge of the aperture occupying approximately half of the trepanned region; no signs of inflammatory response are present. Šlaus (2002) suggested blunt-force trauma as aetiology of the aperture. However, this is highly unlikely since no radial micro-fractures were observed on the surface of the skull under the magnifying glass or the CT scans (*Figure 6*). Although it is highly unlikely that traces of micro-fracture could be observed on CT, major blunt-force trauma would cause surrounding linear macro-fractures, evidence of which would be visible on CT even if healed. Furthermore, on a more macroscopic level, traces of scraping are clearly visible around the edges of the opening. Along with the trepanation, the skull of this individual exhibits mild healed *cribra orbitalia* in both orbits as well as mild healed porotic hyperostosis on both parietal bones.

The cranium from Jagodnjak belongs to a juvenile of about 11 to 13 years of age. The skull is fragmented, although most of the bones are preserved – the only part that is missing post-mortem is the left side of the frontal bone and the left side of the face. On the right side of the frontal bone, 17 mm anterior to the coronal suture, a jagged-edged but oval-shaped aperture 13×9 mm in dimension is present (*Figures 7a, b*). Again, the cranial vault is completely perforated. Due to the poorly preserved cortex, it is not possible to register any signs of infection on the endocranial side. Based on the uneven edges of the aperture on the endocranial side, which could indicate early stages of remodelling, as well as a slight irregularity of the ectocranial side (seen on sagittal CT scans), it could be suggested that the juvenile died shortly after the procedure itself, although the exact cause of death cannot be established with certainty (*Figure 8*). No other pathological changes were recorded on the cranium from Jagodnjak.

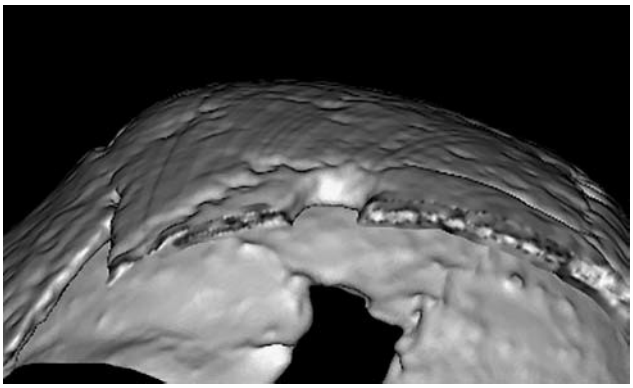

FIGURE 4: Volume rendering technique (VRT), coronal plane /virtual cut-off/, CT scan, Rudine (scan by M. Čavka).

DISCUSSION

The three cases of trepanation presented in this paper provide new insight into surgical methods and practices during the Bronze Age. However, the earliest skeletal evidence of trepanation in Europe may be dated to the Mesolithic (Alt *et al.* 1997, Crubézy *et al.* 2001, Lillie 1998) and certainly to the early Neolithic

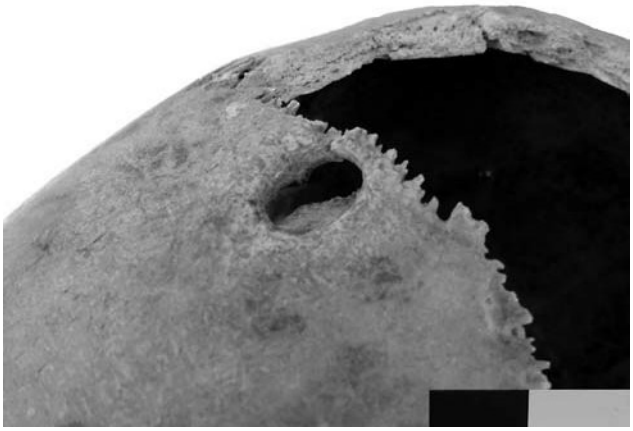

FIGURE 5: The trepanation from Bezdanjača, ectocranial view (photo by M. Carić).

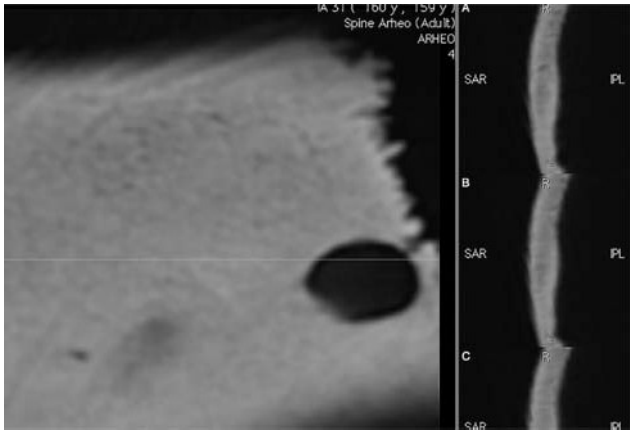

FIGURE 6: Stretched curved multiplanar reconstruction (CPR), CT scan, Bezdanjača (scan by M. Čavka).

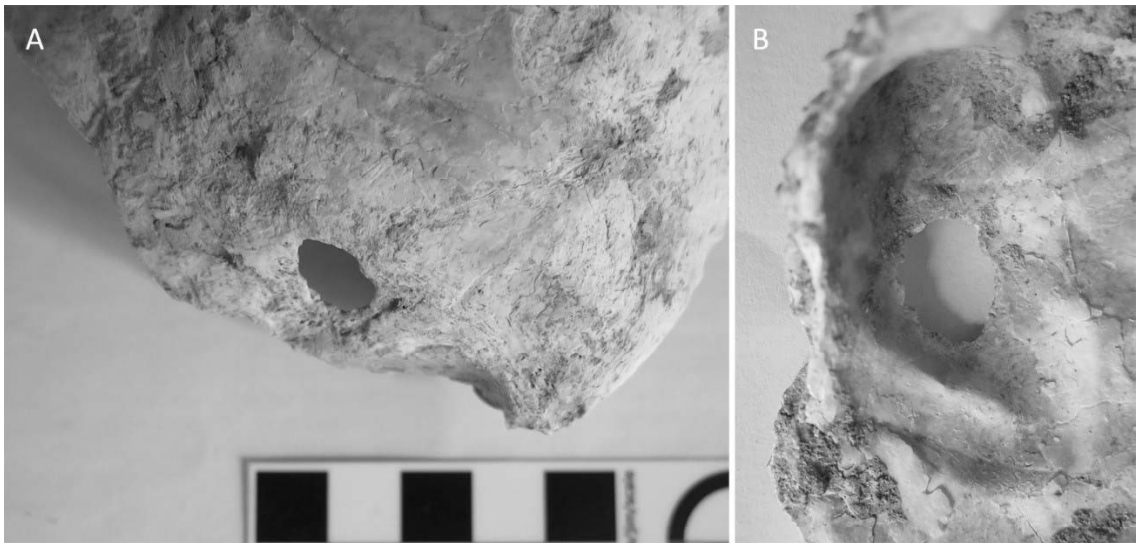

FIGURE 7: The trepanation from Jagodnjak: a) ectocranial view; b) endocranial view (photo by M. Novak).

period (Aufderheide, Rodríguez-Martín 1998, Capasso *et al.* 2002, Liu, Apuzzo 2003, Piek *et al.* 1999). These trepanation examples usually appear in populations of hunter-gatherers from different regions of Europe and North Africa (Crubézy *et al.* 2001). One such eastern European example is from Vasiliyevka III in the Dnieper rapids region of Ukraine, which shows a healed trepanation, as do skulls from Vasiliyevka II and Vovnigi II dating to approximately 10000 BP (Goikhman 1966). An incomplete trepanation case dated to around 6000 BCE was also found at the site of Concheiro da Moita do Sebastião from Muge, Portugal (Jackes *et al.* 1997). It is also important to mention the Early Neolithic examples from Vedrovice in Moravia, Czech Republic (Crubézy 1996), which is one of the oldest LBK (Linear Pottery culture) sites (Podborský 1993). Vedrovice is an excellent trepanation example because the cause for the procedure is known, as the intervention was done following an open cranial injury (Crubézy *et al.* 2001).

Up until recently, the prevailing hypothesis was that the trepanation cases in the Bronze and Iron Age of Europe were few, inherently due to the popularity of cremation and lack of preservation of remains (Lisowski 1967). However, more recent studies revealed numerous cases of trepanations from these periods such as various cases from Bronze Age Greece (Agelarakis 2006, Angel 1971, 1973, 1982, Charles 1958, Liston 2009, Arnot 1997, Mountrakis 2011, Papagrigorakis *et al.* 2014), and the coastal area of the Bronze Age Iberian Peninsula (Campillo 2011, Silva 2003, Silva *et al.* 2016, Tomé 2015/2016). On the other hand, in Austria, in comparison to other European regions, most of the reported trepanations are dated to the Late Iron Age (54%) (Breitwieser 2003), which might suggest a cultural contact or exchange with the Mediterranean world around 400 BCE (Moghaddam 2015).

In the case of the Bezdanjača skull, Malez (1975) originally stated that the difficulty of determining the

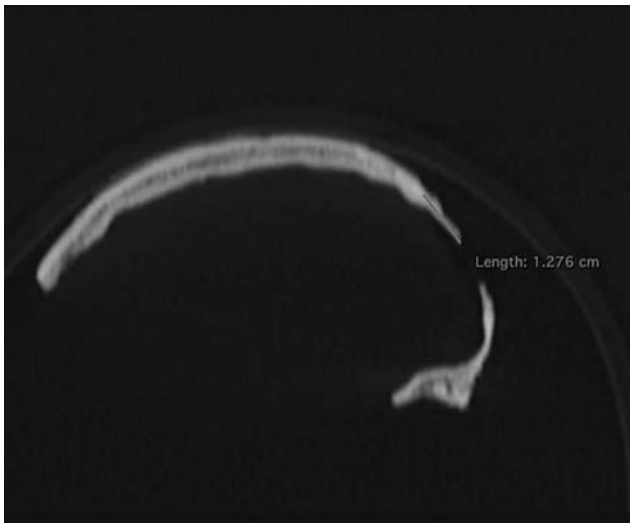

FIGURE 8: Multiplanar reconstruction (MPR), sagital plane, CT scan, Jagodnjak (scan by M. Čavka).

cause of the aperture – whether it was truly the result of an intentional trepanation or a blunt force trauma (as also suggested by Šlaus 2002) – was difficult. As noted previously, CT scans do not exhibit any micro-fractures, which would indicate blunt force trauma, yet the striations caused by scraping are apparent. Therefore, according to the presented data this case most probably represents a case of an intentional trepanation rather than blunt force trauma.

While Mikić (1986) claims that the cause of the patient's death in the Rudine example had been the procedure itself due to the lack of infection, the smooth, remodelled endocranial side of the aperture would indicate otherwise. Along with the aforementioned existence of the minimal infection traces, this could point to the surgeon's skills and effectiveness (in terms of the procedure's duration and/or post-operative treatment). Striations caused by the scraping method are clearly visible around the edges of the aperture.

The case of the juvenile Jagodnjak skull opens a whole new insight into the subject of trepanation, yet the poor preservation of the find prevents us from reaching a definitive conclusion as to the end result of the procedure. Even though the better preserved endocranial side points to a lack of healing process, this may indicate low survival probability. However, such a conclusion must remain only a speculation for the time being. Nonetheless, the Jagodnjak-Krčevine individual is the youngest trepanation subject known in Croatia to date, even though there are other – but few – Bronze Age examples of subadult trepanations from Europe, such as those from Greece (Chlouveraki *et al.* 2008) and Southern Russia (Gresky *et al.* 2016).

A high degree of experience and skill is seen in earlier Neolithic times, and this is especially reflected in high survival rates in the Neolithic times (up to 90%) showing that ancient surgeons respected external landmarks (in terms of not penetrating the *dura mater*), thus yielding such astounding results, according to modern neurosurgical knowledge (Weber, Wahl 2006: 543). The same advanced techniques were applied to the new as well as the two re-analysed Bronze Age skulls from Croatia. Unfortunately, the similar statistics and rates for the Bronze Age are not available.

All three cases and apertures exhibit certain similarities: (i) all are located on the right side of the frontal bone; (ii) all are oval or round-shaped; (iii) in all cases, all three layers of *calvarium* were breached; and (iv) similar techniques for the trepanation procedure were used in all cases. Our analysis suggests that in all three cases the procedure was most likely conducted by the scraping technique. In the majority of other published cases, trepanations were performed on the left side of the skull, the reason for that being the fact that the majority of traumatic lesions from interpersonal violence occur on that side, since the attackers were usually right handed and would thus strike at the victim's opposite side (Lisowski 1967). Ruffer (1919) suggests that the high frequency of trepanations on parietal bones was because this region of the skull was most easily accessible to the surgeon. The latter, squatting in front or behind the patient, held the head with his left arm or fixed it between his knees and operated with his right hand (Lisowski 1967: 659–660). It seems that trepanation location was a matter or convenience rather than specific need. Also, most experts identify the parietal bone was the most frequently trepanned skull element, followed by the frontal, occipital and rarely temporal bones (Lisowski 1967).

It is clear that the three (re)analysed Bronze Age cases from Croatia differ from the aforementioned statistics, both in the position of the aperture and the skull element on which the procedure was performed. These differences might point us to some possible conclusions as to the reason for these variations, either ritual, magical or therapeutic. In all three cases there were no traces of cranial skeletal trauma, which might exclude interpersonal violence as the cause for the procedure, not to mention the low probability of the attackers in all three cases being left-handed. Obviously, here we cannot rule out other medical conditions affecting all age groups such as headaches, epilepsy, and so on. This makes the theory of the presented trepanations being conducted for other medicinal purposes viable, although other published Croatian cases from different time periods do not show such uniformity. However, it says little about why exactly was the right side of the head (and particularly that skeletal element) chosen for the intervention, other than all three surgeons being left-handed. Or, could it be due to some sort of magical beliefs and practices after all? In at least two cases (Bezdanjača and Rudine) the patients survived for a certain period after the operation, since the striations are still visible on the cortex, which would indicate short-term healing. Unfortunately, in the case of the Jagodnjak trepanation extensive post-mortem cortical damage around the edges prevents a detailed analysis into the post-procedural survival of the individual.

Even though explanations for trepanation in prehistory range from medical to magico-ritual reasons,

none of the presented cases so far suggest that the magico-ritual aspect was the primary one. However, this possibility cannot be ruled out, especially since they are located in approximately the same location on the vault rather than randomly placed, which could indicate a primacy for this location in cultural beliefs about the head. It is notable that these cases are not associated with direct trauma to indicate a therapeutic necessity; however, other medical conditions should be also considered. Despite the rather extensive evidence of surgical implementation and expertise regarding trepanation in the prehistoric periods (especially in the previous Neolithic), caution must be made not to presume and conclude that trepanation per se was the origin of neurological surgery of the brain (Weber, Wahl 2006).

CONCLUSION

In this article three prehistoric cases of trepanation from Croatia dated to the Bronze Age are presented, (re)analysed and (re)interpreted. Although these Bronze Age trepanations originate from somewhat different archaeological and geographic contexts, they all share certain similarities in terms of the procedures used, the anatomical position as well as dimensions/shape of the aperture. As such, they represent the oldest cases of intentional medical interventions in the territory of modern-day Croatia known so far (together with the inaccessible specimen from Vrčin), while the Jagodnjak-Krčevine individual is the youngest person thus far discovered with this kind of treatment on this territory.

Croatia has a long and rich archaeological history, but the three Bronze Age trepanations presented here give us further insight into this dangerous and invasive procedure in terms of timeframe as well as the success of the technique itself. The scraping technique used in the procedure, the positions where they were applied (right side of the frontal bone), and the anatomical care with which they were conducted (the breaching of all three layers of *calvarium*) imply a deeply-rooted knowledge, continuity, and thus experience in the intervention that had probably already been in use for generations in this region.

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