

# Craniofacial pathologies in an early adolescent from the Funnel Beaker site of Modřice, Czechia

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**ABSTRACT:** Several craniofacial pathologies are present in an early adolescent from a cemetery (n = 22) associated with a Neolithic Funnel Beaker culture in Modřice, Czechia.

The objective of the study was to document anomalies on the Modřice 3871 cranium, with an emphasis on investigating whether the mid-sagittal suture exhibited synostosis or bridging to account for the visible scaphocephaly.

All available cranial and postcranial elements of the Modřice 3871 early adolescent were examined macroscopically. The cranial vault was subjected to radiography and compared to macroscopic views.

Modřice 3871 is estimated to age to 12–14 years. Macroscopic examination and radiography support a diagnosis of mid-sagittal bridging rather than synostosis for this slender and anteroposteriorly elongated cranium. In comparison, the anterior sagittal, coronal and lambdoidal sutures are completely unfused. Craniofacial asymmetry, cribra orbitalia, porotic hyperostosis of the temporal and the presence of multiple wormian bones indicate additional maturational disruptions.

The scaphocephaly observed in Modřice 3871 is not severe compared to modern clinical manifestations of craniosynostosis. Radiocarbon dated to 3,700–3,600 years BCE, Modřice 3871 presents one of the oldest recorded cases of scaphocephaly. The elongated vault is probably not the result of head-binding given the dearth of anthropogenic cranial reshaping in the Neolithic of Europe. This study adds to the growing recognition of prehistoric and historic craniofacial anomalies which will likely continue as additional human remains are excavated. In addition, the study increases the understanding of the lived experience of prehistoric individuals experiencing visible craniofacial pathologies such as cranial asymmetry and scaphocephaly.

**KEY WORDS:** scaphocephaly, cribra orbitalia, wormian bones, craniosynostosis.



Original article

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## Introduction

Suture closure ages are notoriously variable in humans (Meindl and Lovejoy 1985; Buikstra and Ubelaker 1994; Hershkovitz et al. 1997). When the premature ossification of suture mesenchyme occurs in prenatal or early postnatal development, the cranium continues to grow, but largely within those neurocranial regions unconstrained by premature suture closure, resulting in an abnormal vault morphology (Marsh et al. 1991; Cohen 2005; DeLeon and Richtsmeier 2009; Ursitti et al. 2011; Kajdic et al. 2018; Eisová et al. 2021). Partial or complete ossification of the sagittal mesenchyme during early cranial development results in a visibly narrow head shape or scaphocephaly, often including elevation of the fused suture (Weber et al. 2008; Ursitti et al. 2011; Soficaru et al. 2018).

Scaphocephaly is often the result of sagittal synostosis although the converse is not necessarily true (Cohen 2005; Padmalayam et al. 2013; Groza et al. 2014). Sagittal synostosis is detectable by the third trimester and is the most common form of craniosynostosis, affecting approximately 1 in 5,000 births (Constantine et al. 2000), and is 3.5 times as

common in males compared to females (Cohen 2005; Ursitti et al. 2011; Kajdic et al. 2018). Partial synostosis of the sagittal suture occurs in about a third of cases among infants around one year (Boyajian et al. 2020). As infants age, the partial closure of the sagittal sutures often proceeds to full fusion.

Scaphocephaly has been found in several Neolithic contexts across Europe. The earliest of these include the Eneolithic of Spain and the Neolithic cultures of central Europe (Table 1). The paucity of individuals noted to exhibit scaphocephaly point to the lack of evidence of head binding in comparison to other prehistoric contexts, such as the Neolithic Near East and Pre-Columbian Mesoamerican, Hopi and Andean cultures (Antón 1989; Meiklejohn et al. 1992; Kohn et al. 1994; Gerszten et al. 1998). Here we report a case of scaphocephaly, possibly from sagittal synostosis or partial fusion (bridging), found in an early adolescent cranium from the Neolithic cemetery of Modřice. Scaphocephaly in Modřice 3871 is coupled with other craniofacial pathologies, including facial asymmetry, the presence of wormian bones, cribra orbitalia and porotic hyperostosis of the temporal bone.

Table 1. Scaphocephaly in prehistoric Europe

Site	Location	Identifier	Dating	Sex	Age in years
Kóny <sup>a</sup>	Hungary	SNR 247/1	Linear Pottery Culture	?	6–7
Kóny <sup>a</sup>	Hungary	SNR 247/2	Linear Pottery Culture	?	7
West Kennet Barrow <sup>b</sup>	UK	EU 1.5.148	Neolithic	F	17–25
Zengővárkony <sup>c</sup>	Hungary	Grave Nr. 7	Lengyel	F	20–25
Náměšť na Hané <sup>d</sup>	Czechia	Feature Nr. 7	Funnel Beaker	F	30–50
Cova del Palanques <sup>e</sup>	Spain	Skull Nr. 6	Eneolithic	?	?

<sup>a</sup>Tóth et al. (2009); <sup>b</sup>Cuthbert (2018); <sup>c</sup>Smrčka et al. (2018); <sup>d</sup>Pankowská et al. (2010); <sup>e</sup>Campillo (1993)

## Materials and Methods

### Modřice cemetery

Modřice is located in the southern Moravia region of Czechia (Fig. 1). Extensive excavations recovered a rich prehistoric settlement and burial ground associated with the Funnel Beaker culture. The graves include skeletal remains, mostly without artifacts, and are radiocarbon dated to 3,800–3,600 years BCE (Šmíd et al. 2018, 2021a; Drtikolová Kaupová et al. 2023), corresponding to the late Neolithic or Early Eneolithic in Czech archaeology (Jarošová et al. 2022). The Funnel Beaker culture is associated with a further Neolithization of the incipient agricultural economy that rapidly spread into parts of northwest and northcentral Europe. The Funnel Beaker culture of Modřice was an agrarian community that included domesticated animals, wheat and vegetable cultivation as well as wild foods in the diet.

At Modřice, there were 22 individuals buried in two main groups of single graves, each apparently comprising members of the same household (Šmíd et al. 2018, 2021a); two of the burials

were in a settlement pit and no comingled graves were found. Individuals of both sexes were distributed across the two groups, about a half of whom were immature, including an early adolescent, Modřice 3871. In total there were five children 3–6 years-old, four older children 7–14 years, two adolescent females, six adult males and five adult females. Most of skeletons (including 3871) were deposited in an outstretched position, which was a common burial practice in this phase of the Funnel Beaker culture, although only recently recognized in Moravian archaeology (Šmíd et al. 2021b). The rectangular grave pit of 3871 was oriented NW-SE, and the burial was directly dated to  $4880 \pm 33$  years uncalBP (Drtikolová Kaupová et al. 2023). A subsequent Bronze Age pit located in the lower part of the legs disturbed the grave of Modřice 3871, and the bones were partially scattered, probably by animals (rodents). Some of the skeletal remains were partly fractured and many smaller bones of the hands and feet were missing (Fig. 2).

There are multiple paleopathologies found at Modřice, including spina bifida, spondylolysis and ankylosis of the lumbar

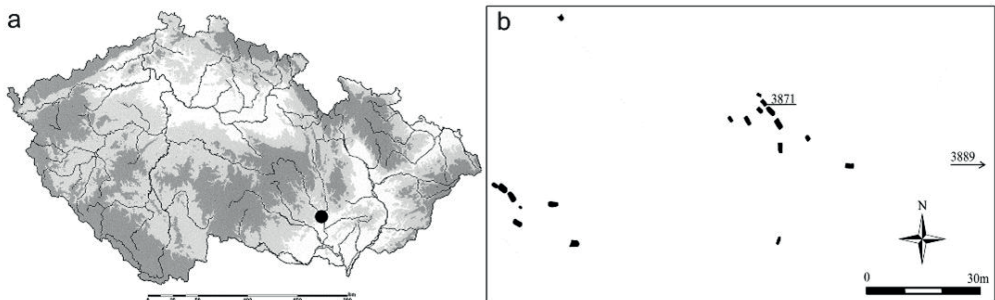


Fig. 1. Map of (a) Czechia showing the location of the Neolithic cemetery of Modřice indicated by the black circle; and (b) the cemetery showing the two main groups of graves and the position of Modřice 3871 vis-à-vis the other graves

vertebrae, entheses, clavicle and cervical asymmetry, healed and perimortem fractures, osteophytosis, osteoporosis, periosteal reactions and other skeletal abnormalities (Šmíd et al. 2021a, Table V). The dental health noted at the Modřice cemetery was rather poor with a relatively greater prevalence of caries compared to other Neolithic population from Moravia and East Bohemia (Jarošová et al. 2022).

## Methods

Modřice 3871 was examined at the Moravian Museum in Brno, Czechia (Inv. nr. A25632) using macroscopic investigation to estimate the age and describe the preservation and morphology. Dental wear scores following Smith (1984) were used to characterize molar attrition to corroborate the age estimate. Radiographic images of Modřice 3871 were obtained at Fakultní nemocnice U sv. Anny v Brně (St. Anne's University

Hospital in Brno), and these were compared to the macroscopic examination of the cranial vault.

## Results

### Inventory

The grave of Modřice 3871 consists of a single incomplete early adolescent skeleton. The cortical surface is slightly eroded in places, and covered with calcareous debris. The bones are brownish-yellow in color (Fig. 2).

### Cranial vault

The cranium of Modřice 3871 is relatively well preserved and partially reconstructed (Fig. 3). The cranial vault base is slightly deformed by the position of the basi-occipital bone, which is conjoined with the two lateral occipitals and slightly rotated to the left. The foramen magnum is nearly intact excepting a posterior margin with possible rodent gnaw marks.

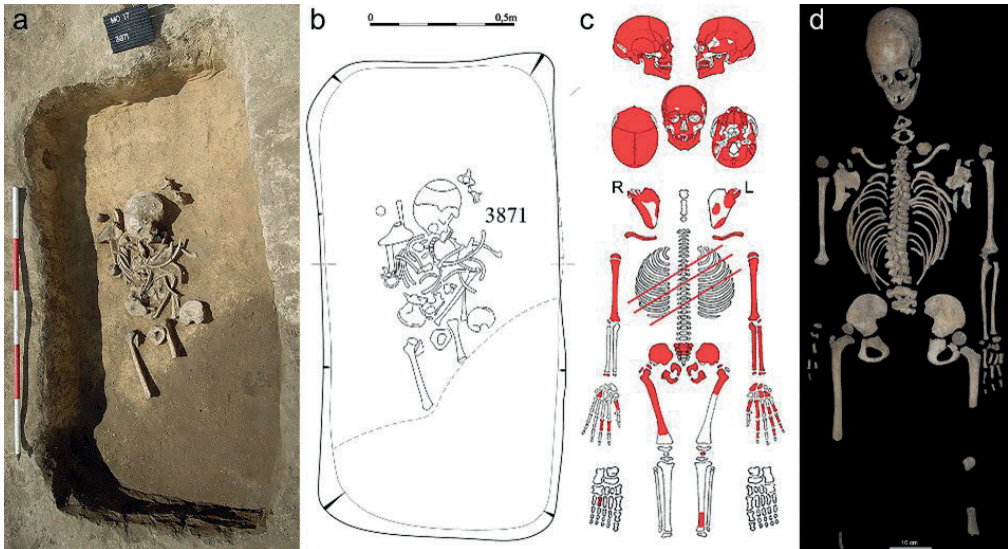


Fig. 2. Modřice 3871 (a) photograph and (b) drawing showing the skeleton *in situ*; (c) scheme of preservation, R = right, L = left; and (d) skeletal elements in anatomical position

The frontal and occipital bones are complete, whereas the parietal bones are reconstructed after recent fracturing in the area of the parietal tubercles. The damage is confined mostly along the parietal-occipital margin, and extends to the right occipitomastoid region. The right temporal bone is almost complete, whereas the left is damaged. The sphenoid body and greater wings are partly preserved.

The cranial vault is markedly expanded anteroposteriorly from a maximum cranial length (gonion to opistocranium = 185 mm) much greater than the maximum cranial breadth (euryon to euryon = 124 mm). The occipital extends posteriorly forming a relatively concave inferior contour in which the inferior squama abruptly tapers anteriorly forming a small

occiput, with a sigmoid curvature extending further inferiorly to opisthion (Fig. 3).

### Face and dentition

The relatively vertical frontal squama exhibits slight but palpable superciliary arch development. Much of the splanchnocranium is missing, although the palate connects to the mid-face (Fig. 3). The posterior mid-face is partly damaged owing to the destruction of the inferior left and right palatine bones and the adjoining maxillary palatal border, while the mandible is complete.

The permanent dentition is mostly preserved *in situ*. On the maxilla, only the right canine and left I<sup>2</sup> are missing postmortem, while the unerupted M<sup>3</sup> is visible on both sides. On the mandible, only I<sub>1</sub> on both sides and left I<sub>2</sub> are lost postmortem.

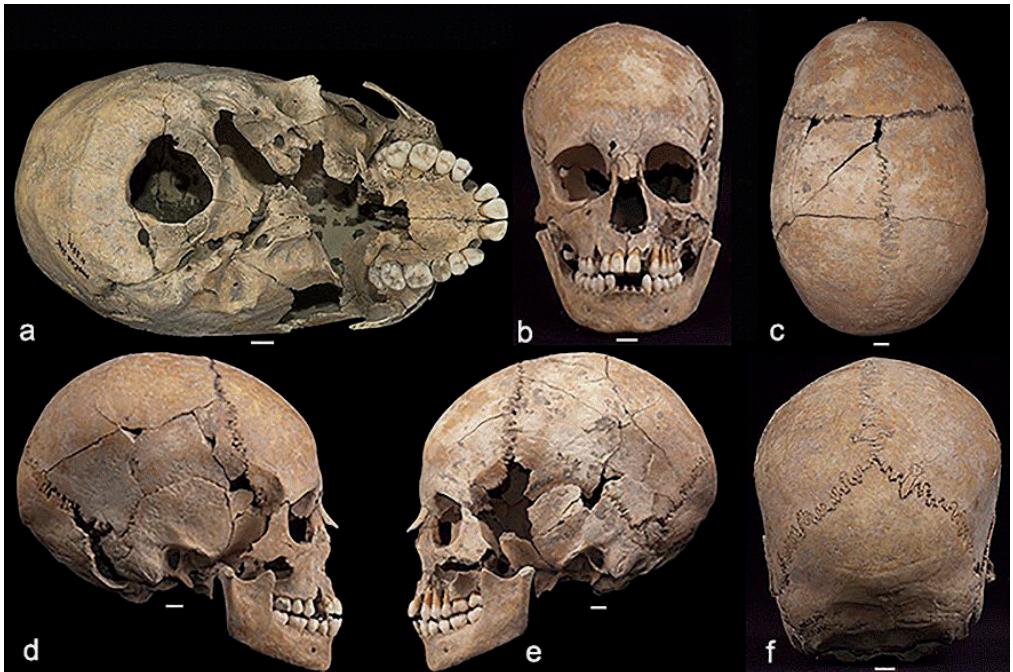


Fig. 3. Modřice 3871, (a) inferior view showing the elongated cranial vault; as well as (b) anterior; (c) superior; (d) lateral right; (e) lateral left; and (f) posterior planes; scale bars = 1 cm

### Postcranial skeleton

The vertebrae ribs, scapulae and clavicle are well preserved. The humeri are also nearly complete and include separated proximal epiphyses without any fusion evident. From the right forearm, only the distal epiphysis of the radius is preserved. The forearm bones of the left are intact except for the proximal epiphyses. Five carpal bones, 5 metacarpals and 9 phalanges are preserved (Fig. 2).

The ischium and pubis are fused but are separated from the ilium. The right femur is largely preserved but misses the distal end of the shaft and epiphysis, although the greater and lesser trochanter and head epiphyses are present. There are gnaw marks on the diaphysis of the right femur. On the left femur, only the proximal third of the diaphysis is preserved, as is the distal diaphysis of the left tibia and the right fifth metatarsal (Fig. 2).

### Age and sex estimation of Modřice 3871

Based on visual examination of the size of the cranium, the small and orthogonal face, and lack of coronal and lambdoial ossification (Fig. 3), the individual is aged as an early adolescent (Scheuer and Black 2000; Scheuer 2002). All of the permanent teeth have erupted with the exception of the third molars, which are deeply embedded within the crypts, although the crowns are fully formed and the growth of roots has commenced. The permanent teeth, and in particular  $M_2$  and  $M^2$  show minimal attrition or Stage 2, whereas  $M^1$  is consistent with Stage 3 (Smith 1984).

The lack of fusion of epiphyses of the preserved appendicular skeleton provide additional corroboration of an immature age (Scheuer and Black 2000). These include the femoral head, the greater and lesser trochanters and distal tibial epiphysis, the fused ischiopubis and ilium

articulation, the humeral head and distal trochlear end of the humerus, the proximal head and distal styloid processes of the radius and the proximal olecranon and distal styloid processes of the ulna (Fig. 2). Many of these epiphyses fuse during the late teens. However, the superior ischial and inferior pubic rami fuse at 6–9 years (Steele and Bramblett 1988), while the lesser trochanter of the femur and proximal radius commence fusion at 15–16 and 16 years respectively (Steele and Bramblett 1988), suggesting Modřice 3871 can be confidently aged between these extremes. The fact that the ischio-pubic fusion site is still visible could suggest an individual not much older than 9 years. The triradiate cartilage joining the three innominate bones of Modřice 3871 is unfused (Fig. 2). The triradiate commences from multiple epiphyses, including a posterior one forming around 10–11 years, which eventually joins an anterior epiphysis around 12–14 years and these fuse with the epiphysis of the anterior inferior iliac spine, which forms at 14 years (Scheuer and Black 2004). The *os coxa* is completely ossified by 19 years (Scheuer and Black 2004). Modřice 3871 does not present any notable fusion of these triradiate epiphyses and lacks an anterior inferior iliac spine suggesting an age younger than 14 years. The unfused distal humerus which commences ossification at 14 years (Steele and Bramblett 1988) further corroborates an early adolescent attribution. There are no instances of the skeletal remains showing epiphyseal fusion that would be unusual for an early adolescent. The length of the long bones and state of fusion of all the epiphyses taken together indicate an age 10–13 years (Scheuer and Black 2000) while tooth eruption, including the slight wear on the fully erupted second molar,

indicates an age closer to 14 years (Al Qhatani et al. 2010). The lack of sexually diagnostic features on the pelvis, cranium and mandible and the immature age of the individual prevented an estimation of sex membership.

### Diagnosis

Although taphonomic processes have fractured and slightly distorted the cranium, the unusual elongated shape of the vault is unambiguous (Fig. 3). Weber et al. (2008) calculate a mean cranial length/breadth index for untreated scaphocephalic adult crania from historical and archaeological collections to be 63.4 ( $n = 18$ ). The mean length/breadth index for adult crania without stenosis is 78.9 ( $n = 40$ ) (Weber et al. 2008). The length/breadth index for Modřice 3871 is 67.0, which is lower than then mean of 74.3 for the six complete adolescent and adult crania from Modřice (Šmíd et al. 2021a). The cranial index of the other adolescent from Modřice excavated from grave 3858 (female, 15–19 years) is 80.3.

The superior surface of the orbital wall exhibits cribra orbitalia (Fig. 4) indicative of nutritional stress. The superior ceiling of both orbits presents cribra orbitalia Grade 1–2 (Rivera and Lahr 2017) or Type 2–3 in the antero-intermediate sector following Stuart-Macadam

(1991) (Fig. 4). Porosity is also evident in the area of *porus accusticus externus*.

In addition, the upper facial skeleton also appears slightly deformed. The right supraorbital rim is higher and more bulbous than the left in inferior view (Fig. 3 and Fig. 4). This difference is likely not the result of taphonomic processes since the bony table is mostly uninterrupted across the supraorbital margin. The right orbit is also shaped differently than the left. Whereas the left is relatively circular, the right orbit is wider, shorter, and more trapezoidal in shape (Fig. 4). There is also asymmetry in the partly preserved superior portions of the nasal bones in which the right is broader than the left.

Additional asymmetry exists in the superior shape of the cranial vault, such that the right lateral parietal arch bulges slightly laterally compared to the left (Fig. 3). In addition, the sagittal suture veers slightly to the left approaching the coronal suture about 10 to 15 degrees from the sagittal plane (Fig. 3). Although some of this distortion could possibly be from taphonomic factors, the slight but visible asymmetry at multiple locations on the upper face and vault, combined with mid-sagittal partial fusion could signal the presence of a syndromic synostosis involving multiple deformities (Ursitti et al. 2011; Kajdic et al. 2018). Howev-

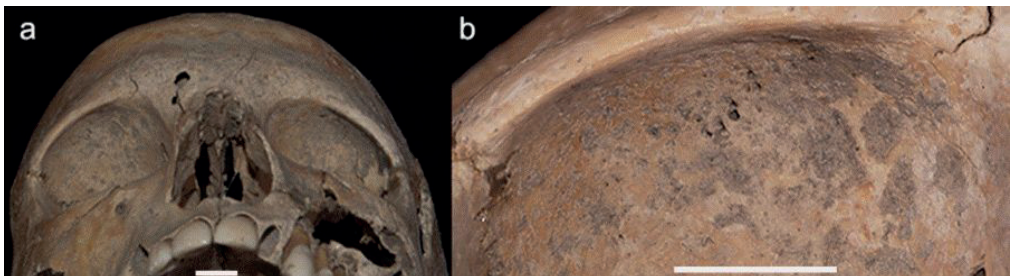


Fig. 4. Cribra orbital (a) viewed inferior on the orbital ceiling of the frontal bones; (b) the right orbital ceiling at a higher objective shows the lesions appear to be healing; both scale bars = 1 cm

er, the coronal and lambdoidal sutures lack any evidence of closure, suggesting nonsyndromic synostosis (Giuffra et al. 2013) (Fig. 3).

The suture morphology is rugged and continuous, with the exception of an intervening wormian ossicle in the posterior sagittal suture (Fig. 3). Two additional wormian bones are located in the occipitomastoid sutures of the right and left sides (Fig. 3). Another double ancillary ossicle is found in the right lambdoidal suture (*ossiculum suturae lambdoideae*).

Radiography of Modřice 3871 corroborates the mid-sagittal partial closure endocranially (Fig. 5). Like the ectocranial surface, the endocranium features an unfused coronal, anterior sagittal and lambdoidal suture. The mid- and posterior sagittal suture areas are represented by a faint line that demarcates the fusion site and the lack of two independent pa-

rietal bones in Modřice 3871 (Fig. 5). The radiological and macroscopic analyses confirm that the mid-sagittal suture exhibits partial fusion endocranially and ectocranially, while the coronal and lambdoidal are open. Rather than the classic definition of sagittal synostosis (White 1996), it appears that the formation of bone spicules that cross the suture, or bridging, could be present (Fig. 5). The ectocranial surface presents a suture partly filled with matrix, suggesting an opening sufficient to collect debris (Fig. 5). Therefore, a diagnosis of bone bridging rather than synostosis is advanced to characterize the partial fusion of the sagittal suture.

It is possible that Modřice 3871 suffered from Klippel-Feil syndrome given the asymmetry of the face and bridging of the mid-sagittal suture (Herrerín et al. 2022). Basilar impression is also

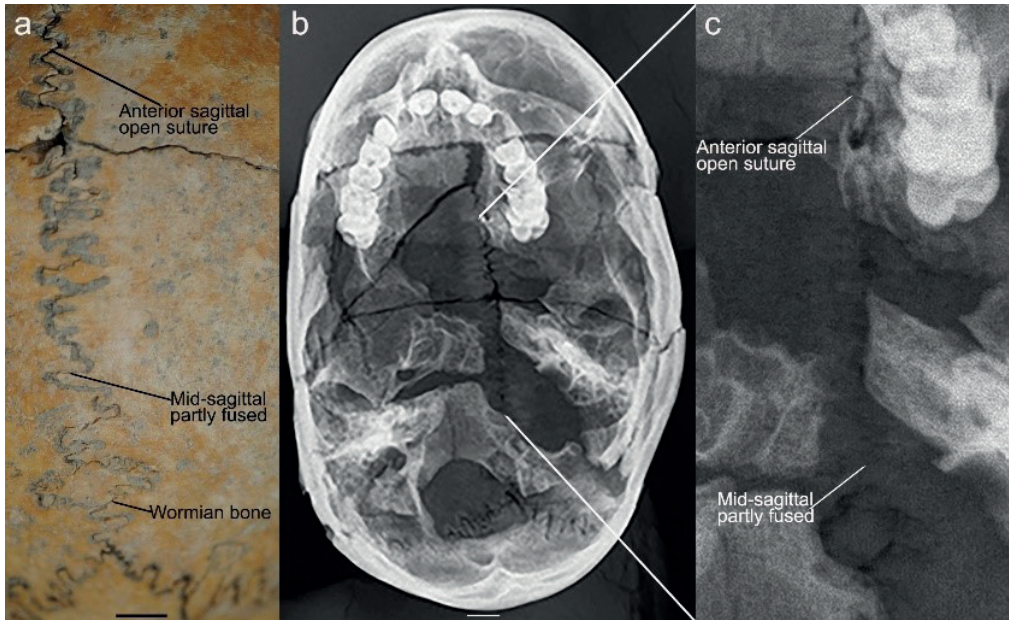


Fig. 5. Modřice 3871 cranial vault (a) superior view, showing the mid-sagittal suture ectocranially and a sagittal wormian bone; (b) radiograph of the cranium; and (c) enlarged area on the radiograph showing the mid-sagittal suture; scale bars = 1 cm



associated with Klippel-Feil syndrome. The basilar region of Modřice 3871 is slightly displaced inferiorly. Yet Modřice 3871 lacks the concavity of the posterior occipital squama, sphenoid and petrous portion of the temporal surrounding the foramen magnum that characterizes basilar impression (Chamberlain 1939; Herrerín et al. 2022; Fig. 3). In addition, the cervical vertebrae do not show ankylosis, severe osteophytosis or any notable ossification (Fig. 2); the sagittal suture is not ossified along its entire length; and no large parietal foramina are present (Herrerín et al. 2022). Although craniofacial asymmetry and sagittal suture bridging exist, Klippel-Feil syndrome, which is not associated with the formation of wormian ossicles, is an unlikely diagnosis for Modřice 3871.

### Discussion

Scaphocephaly is often the result of untreated sagittal synostosis, which is most common in the posterior and middle portion of the suture (Marsh et al. 1991; Cohen 2005; Ursitti et al. 2011). Constriction of the fetal neurocranium, including the base, during the third trimester does seem to correlate with sagittal synostosis, which may explain a greater prevalence in males who have larger skulls, even during gestation (White 1996). Constriction or mechanical stress results in a close alignment of cranial ossification centers during the sensitive periods of prenatal dura development that could influence the expression of sagittal synostosis (DeLeon and Richtsmeier 2009; Padmalayum et al. 2013).

Sagittal synostosis is one of the most common human craniofacial anomalies, and is usually apparent to external observers by the end of the first year (Garcia et al. 2009). By the second year of life,

most cases of sagittal synostosis exhibit complete fusion of the sagittal suture (Kohn et al. 1994), although early closure of a sagittal suture does not necessarily result in scaphocephaly (Cohen 2005; Padmalayum et al. 2013; Groza et al. 2014). The degree of cranial elongation would depend on the timing of the closure.

### Prehistory of scaphocephaly

Scaphocephaly has been noted since antiquity (Padmalayum et al. 2013), and was present at least as early as the Middle Pleistocene (Garcia et al. 2009). Modřice 3871 presents one of the most ancient examples of scaphocephaly although there are others. Three from Hungary are earlier. Two of these are from the latter half of the 6<sup>th</sup> millennium BCE (Tóth et al. 2009), and another is dated to 4,500–4,300 BCE (Smrčka et al. 2018). At Náměšć na Hané, a cranium dated to a slightly earlier time period but also from a Funnel Beaker culture settlement in Moravia, exhibits sagittal synostosis and is associated with a cranial index of 55 (Pankowská et al. 2010). Relative to the female from Náměšć na Hané, Modřice 3871 may have presented mild scaphocephaly that probably arose from postnatal bridging of the sagittal suture.

Although head binding causes significant closure to the sagittal suture (White 1996), only one individual, Modřice 3871, out of both cemetery plots (Fig. 1) exhibits this elongated cranial form. Head binding was widely practiced in the Americas to denote status and identity (Antón et al. 1992; Meiklejohn et al. 1992; White 1996). Eurasian head binding has also been documented although more rarely and is often associated with cultures characterized by stricter hierarchies and greater contact among diverse peoples than

would be typical for a small-scale Neolithic society like Modřice (Meiklejohn et al. 1992; Fernandes et al. 2019).

### **Wormian bones**

Both tensile and compressive forces act to prematurely fuse the suture in affected individuals (White 1996). These forces also tend to be implicated in the formation of wormian bones (White 1996; Sanchez-Lara et al. 2007). Their presence is consistent with other studies noting wormian bones in individuals exhibiting premature sagittal fusion (White 1996). Sagittal and other synostoses as well as wormian bones, have been considered by some to be adaptive responses to prenatal constraints on the developing cranium (Moss 1959; White 1996; Pedersen and Antón 1998; Cohen 2005). Whether these ancillary ossicles are related to the presentation of partial fusion of the mid-sagittal suture is unknown. However, the presence of wormian bones do suggest some irregularities of sutural development during early embryogenesis.

However, one of the wormian bones of Modřice 3871 is found in the sagittal suture which is rare (Fig. 5). Most wormian bones occur in the lambdoidal suture or at lambda and less often in the occipitomastoid (Safak et al. 2020) and coronal sutures (Bellary et al. 2013). Some studies report an absence of sagittal sutural bones (Safak et al. 2020) whereas others demonstrate its presence albeit in small numbers (Vijay et al. 2017). Pryles and Khan (1979) suggest wormian bones to be a marker of central nervous system abnormality, craniosynostosis and other anomalies although its presence in 61% of individuals in one study (Vijay et al. 2017) and 59% in another (Cirpan et al. 2015) may indicate a lack of con-

cordance between sutural ossicles and other disorders. However, the presence of several wormian bones may signal the existence of other anomalies (Cremin et al. 1982). This is the case for Modřice 3871 in which 5+ are found at multiple locations. Given the bridging of the mid-sagittal suture (Fig. 5), the presence of a sagittal wormian bone offers greater support for linking these anomalies to dural mechanical stress during maturation, either pre- or postnatally, that adversely affected cranial development. The placement of the sagittal wormian bone observed in Modřice 3871, approximately 2 cm superior to lambda, also approximates the position of the third fontanelle, which is associated with other birth defects (Chemke and Robinson 1969). It is possible that the sagittal wormian bone formed to compensate for a third fontanelle, although it remains unknown.

### **Cribralia orbitalia and nutrition**

The nutritional stress indicated by the presence of cribralia orbitalia is also noteworthy. In addition to its manifestation on Modřice 3871, cribralia orbitalia affected another 4 individuals from the cemetery, and nearly all are children (4 of 5). Altogether, cribralia orbitalia was present in 38.5% of available individuals (5 of 13) indicating nutritional and/or disease stress broadly affected this Neolithic farming community, particularly its youngest members (Šmíd et al. 2021a). Other indices of nutritional stress include porosity of the temporal and asymmetry of the face. Furthermore, wormian bones were present in 8 out of 15 individuals (53.3 %) (Šmíd et al. 2021a), suggesting a possible genetic or behavioral influence on cranial suture formation in the community. Although the presentation of

skeletal abnormalities at this cemetery is widespread (Šmíd et al. 2021a), the combination of paleopathologies in Modřice 3871 is unique.

The analysis of stable isotopes of individuals from Modřice shows that this community did not differ from other Funnel Beaker populations in the region, whose diet was of a terrestrial origin with a dominant C3-plant component supplemented with animal products (Drtiková Kaupová et al. 2023). The isotope values for Modřice 3871 ( $\delta^{15}\text{N} = 9.5$ ,  $\delta^{13}\text{C} = -19.8$ ) fall close to the average of the Modřice population ( $\delta^{15}\text{N} = 9.5$ ;  $\delta^{13}\text{C} = -19.6$ ). Cribra orbitalia could have been the result of any number of processes, acting alone or in combination, including nutritional stress, anemia, infections and parasites, all of which are connected to a Neolithic agrarian lifestyle. The lack of agreement between older dental and younger epiphyseal age estimates may also point to nutritional stress.

### Asymmetry of the basicranium

In Modřice 3871, the basicranium is tilted to the left (Fig. 2). Although the possibility remains that taphonomic processes distorted the basicranium, it is unlikely given the corroborating evidence of asymmetry in the facial skeleton and superior cranial vault. Furthermore, the observed basicranial deformation may be associated with mid-sagittal bridging given the intertwined ontogenetic processes governing the formation of the vault and the base (Moss 1959; Antón 1989; DeLeon and Richtsmeier 2009; Ursitti et al. 2011). Asymmetry of the face and vault favoring the right side is consistent with the directionality of the foramen magnum and basion pointing to the smaller left side of the basicranium (Fig. 2). The combination of cranial asymme-

try, scaphocephaly, multiple wormian bones, cribra orbitalia and porosity of the temporal are suggestive of multiple stressors during development, potentially including epigenetic and nutritional constraints.

## Conclusion

The long narrow cranial shape, caused by endo- and ectocranial mid-sagittal bone bridging, indicates Modřice 3871 represents one of the oldest recorded instances of scaphocephaly in human history (Weber et al. 2008; Tóth et al. 2009; Pankowská et al. 2010; Smrčka et al. 2018). With respect to the lived experience, Modřice 3871 may have had an unusual head shape and slight facial asymmetry. The cribra orbitalia and porosity in the temporal bone indicates nutritional deficiencies or disease-related complications (Armélagos et al. 2014), which could have compromised the life expectancy of Modřice 3871. Nevertheless, Modřice 3871 was buried similarly to the others in the cemetery as has been reported for other prehistoric adolescents with visible congenital cranial anomalies (Pedersen and Antón 1998; Garcia and Santos 2020).

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### Conflict of interests

The authors have no conflicts of interest to declare.

### Authors' contribution

The concept for the paper was developed by FLW and ZT in consultation with DP. The analysis, description and figures were prepared by FLW and ZT. The radiography was coordinated by ZT.

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### References

- Al Qahtani SJ, Hector MP, Liversidge HM. 2010. The London atlas of human tooth development and eruption. *Am J Phys Anthropol* 142:481–90. <https://doi.org/10.1002/ajpa.21258>
- Antón SC. 1989. Intentional cranial vault deformation and induced changes in the cranial base and face. *Am J Phys Anthropol* 79:253–67.
- Antón SC, Jaslow CR, Swartz SM. 1992. Structural complexity in artificially deformed human (*Homo sapiens*) crania. *J Morphol* 24:321–32.
- Armelagos GJ, Sirak K, Werkema T, Turner BL. 2014. Analysis of nutritional disease in prehistory: the search for scurvy in antiquity and today. *Int J Paleopath* 5:9–17. <https://doi.org/10.1016/j.ijpp.2013.09.007>
- Bellary SS, Steinberg A, Mirzayan N, Shirak M, Tubbs RS, Cohen-Gadol AA, Loukas M. 2013. Wormian bones: a review. *Clin Anat* 26:922–27. <https://doi.org/10.1002/ca.22262>
- Boyajian MK, Al-Samkari H, Nguyen DC, Naidoo S, Woo AS. 2020. Partial suture fusion in nonsyndromic single-suture craniosynostosis. *Cleft Palate-Craniofacial J* 57:499–505. <https://doi.org/10.1177/1055665620902299>
- Buikstra JE, Ubelaker DH. 1994. Standards for Data Collection from Human Skeletal Remains: Proceedings of a Seminar at the Field Museum of Natural History. Fayetteville, AR: Arkansas Archeological Survey Research Series No 44.
- Chamberlain WE. 1939. Basilar impression (platybasia). A bizarre developmental anomaly of the occipital bone and upper cervical spine with striking and misleading neurologic manifestations. *Yale J Biol Med* 11:487–96.
- Chemke J, Robinson A. 1969. The third fontanelle. *J Pediatrics* 75:617–22.
- Cirpan S, Aksu F, Mas N. 2015. The incidence and topographic distribution of sutures including wormian bones in human skulls. *J Craniofac Surg* 26:1687–90. <https://doi.org/10.1097/SCS.0000000000001933>
- Cohen MM, Jr. 2005. Editorial: perspectives on craniosynostosis. *Am J Med Genet* 136A:313–26. <https://doi.org/10.1002/ajmg.a.30757>
- Constanine S, Kiermeier A, Anderson P. 2020. Sonographic indicators of isolated fetal sagittal craniosynostosis during pregnancy. *J Med Imaging Radiation Oncology* 64:626–33. <https://doi.org/10.1111/1754-9485.13068>
- Cremin B, Goodman H, Spranger J, Beighton P. 1982. Wormian bones in osteogenesis imperfecta and other disorders. *Skeletal Radiol* 8:35–38. <https://doi.org/10.1007/BF00361366>
- Cuthbert GS. 2018. Enriching the Neolithic: the forgotten people of the barrows. PhD Thesis, University of Exeter.
- DeLeon VB, Richtsmeier JT. 2009. Fluctuating asymmetry and developmental insta-

- bility in sagittal craniosynostosis. *Cleft Palate Craniofac J* 46:187–96. <https://doi.org/10.1597/08-001.1>
- Drtikolová Kaupová S, Jarošová I, Bíšková J, Hrnčíř V, Květina P, Neugebauer-Maresch C, Pokutta DA, Řídký J, Tvrđý Z, Vytlačil Z, Trampota F. 2023. The diet of settled Neolithic farmers of east-central Europe: isotopic and dental microwear evidence. *Archaeol Anthropol Sci* 15:21. <https://doi.org/10.1007/s12520-023-01720-9>
- Eisová S, Naňka O, Velemínský P, Bruner E. 2021. Craniovascular traits and braincase morphology in craniosynostotic human skulls. *J Anat* 239:1050–65. <https://doi.org/10.1111/joa.13506>
- Fernandes D, Sirak K, Cheronet O, Howcroft R, Čavka M, Los D, Burmaz J, Pinhasi R, Novak M. 2019. Cranial deformation and genetic diversity in three adolescent male individuals from the Great Migration Period from Osijek, eastern Croatia. *PLoS ONE* 14(8):e0216366. <https://doi.org/10.1371/journal.pone.0216366>
- Garcia SJ, Santos AL. 2020. Osteological evidence of short stature and parieto-squamosal arch craniosynostosis in a non-adult male from the 13<sup>th</sup> century Leiria, Portugal. *Int J Osteoarch* 30:145–54. <https://doi.org/10.1002/oa.2842>
- Gerszten PC, Gerszten E, Allison MJ. 1998. Diseases of the skull in Pre-Columbian South American mummies. *Neurosurgery* 42:1145–51. <https://doi.org/10.1097/00006123-199805000-00114>
- Giuffra V, Bianucci R, Milanese M, Fornaciari G. 2013. A probable case of non-syndromic brachycephaly from 16th century Sardinia (Italy). *Int J Paleopath* 3:134–37. <https://doi.org/10.1016/j.ijpp.2013.05.005>
- Gracia A, Arsuaga JL, Martínez I, Lorenzo C, Carretero JM, de Castro JMB, et al. 2009. Craniosynostosis in the Middle Pleistocene human Cranium 14 from the Sima de los Huesos, Atapuerca, Spain. *Proc Natl Acad Sci USA* 106:6573–78. <https://doi.org/10.1073/pnas.0900965106>
- Groza V-M, Simalcsik A, Bejenaru L, Simalcsik R-D. 2014. Osteopathies in the population of old Iasi City (Romania): the necropolis of the “Banu” church, 16<sup>th</sup>–19<sup>th</sup> centuries. *Analele Științifice ale Universității „Alexandru Ioan Cuza” din Iași, s. Biologie animală*, Tom LX:91–104.
- Herrerín J, Dorado E, Galassi FM, Varoto E, Dinarès Solà R. 2022. Klippel-Feil Syndrome: morphological findings in a 19th-century musealized skull from Viana del Bollo (Orense, Spain). *Anthropol Rev* 85:63–78. <https://doi.org/10.18778/1898-6773.85.2.03>
- Hershkovitz I, Latimer B, Dutour O, Jellema LM, Wish-Baratz S, Rothschild C, Rothschild BM. 1997. Why do we fail in aging the skull from the sagittal suture? *Am J Phys Anthropol* 103:393–99. [https://doi.org/10.1002/\(SICI\)1096-8644\(199707\)103:3<393::AID-AJPA8>3.0.CO;2-R](https://doi.org/10.1002/(SICI)1096-8644(199707)103:3<393::AID-AJPA8>3.0.CO;2-R)
- Jarošová I, Fojtová M, Tvrđý Z, Kala J, Beran-Cimbůrková P, Brzobohatá H, Trampota F. 2022. Dental health and diet in the middle and late Neolithic (4900–3400 BC): a study of selected microregions in the Czech Republic. *Anthropologie* LX:351–78.
- Kajdic N, Spazzapan P, Velnar T. 2018. Craniosynostosis – recognition, clinical characteristics, and treatment. *Bosn J Basic Med Sci* 18:110–16. <https://doi.org/10.17305/bjbms.2017.2083>
- Kohn LAP, Vannier MW, Marsh JL, Cheverud JM. 1994. Effect of premature sagittal suture closure on craniofacial morphology in a prehistoric male Hopi. *Cleft Palate-Craniofacial J* 31:385–96. [https://doi.org/10.1597/1545-1569\\_1994\\_031\\_0385\\_eopssc\\_2.3.co\\_2](https://doi.org/10.1597/1545-1569_1994_031_0385_eopssc_2.3.co_2)
- Marsh JL, Jenny A, Galic M, Picker S, Vannier W. 1991. Surgical management of sagittal synostosis: a qualitative evaluation of two techniques. *Neurosurg Clin N Am* 2:629–40.

- Meiklejohn C, Agelarakis A, Akkermans PMMG, Smith PEL, Solecki R. 1992. Artificial cranial deformation in the proto-Neolithic and Neolithic Near East and its possible origin: evidence from four sites. *Paléorient* 18:83–97.
- Meindl RS, Lovejoy CO. 1985. Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the lateral anterior sutures. *Am J Phys Anthropol* 68:57–66.
- Moss ML. 1959. The pathogenesis of premature cranial synostosis in man. *Acta Anat. (Basel)*, 37:351–70.
- Padmalayam D, Tubbs RS, Loukas M, Cohen-Gadol AA. 2013. Absence of the sagittal suture does not result in scaphocephaly. *Childs Nerv Syst* 29:673–77. <https://doi.org/10.1007/s00381-012-2005-4>
- Pankowská A, Peška J, Vrána J. 2010. Congenital cranial defect in a female from a Funnel Beaker Culture settlement burial in Náměšť na Hané (Czech Republic) – a case report. *Interdisciplinaria Archaeologica* 1:77–89. <https://doi.org/10.24916/IANS.A.2010.1-2.8>
- Pedersen SC, Antón SC. 1998. Biconal synostosis in a child from historic Omaha cemetery 25DK10. *Am J Phys Anthropol* 105:369–78. [https://doi.org/10.1002/\(SICI\)1096-8644\(199803\)105:3<369::AID-AJPA6>3.0.CO;2-M](https://doi.org/10.1002/(SICI)1096-8644(199803)105:3<369::AID-AJPA6>3.0.CO;2-M)
- Pryles CV, Khan AJ. 1979. Wormian bones. A marker of CNS abnormality? *Am J Dis Child* 133:380–82.
- Rivera F, Mirazón Lahr M. 2017. New evidence suggesting a dissociated etiology for cribra orbitalia and porotic hyperostosis. *Am J Phys Anthropol* 164:76–96. <https://doi.org/10.1002/ajpa.23258>
- Safak NK, Taskin RG, Yücel AH. 2020. Morphologic and morphometric evaluation of the wormian bones. *Int J Morphol* 38:69–73.
- Sanchez-Lara PA, Graham JM Jr, Hing AV, Lee J, Cunningham M. 2007. The morphogenesis of Wormian bones: a study of craniosynostosis and purposeful cranial deformation. *Am J Med Genet Part A* 143A:3243–51. <https://doi.org/10.1002/ajmg.a.32073>
- Scheuer L. 2002. Application of osteology to forensic medicine. *Clin Anat* 15:297–312. <https://doi.org/10.1002/ca.10028>
- Scheuer L, Black S. 2000. *Developmental Juvenile Osteology*. London: Elsevier Academic Press.
- Scheuer L, Black S. 2004. *The Juvenile Skeleton*. London: Elsevier Academic Press.
- Šmíd M, Tvrđý Z, Parma D, Kos P. 2018. Pohřebišťe kultury nálevkovitých pohárů s pohřby v natažené poloze z Modřic, okr. Brno-venkov. *Acta Musei Moraviae* 103:101–40.
- Šmíd M, Kos P, Parma D, Prichystal A, Tvrđý Z. 2021a. Eneolitické osídlení lokality Modřice-Rybníky (okr. Brno.venkov). *Pravěk Supplementum* 36. Ústav archeologické památkové péče Brno, v. v. i., Brno (ISBN 978-80-86399-71-3; ISSN 1804-5731).
- Šmíd M, Lečbych M, Šmerda J, Kala J, Limburský P. 2021b. Sídliště a pohřebišťe kultury nálevkovitých pohárů v Dambořicích, okr. Hodonín. Příspěvek k poznání pohřebišť s pohřby v natažené poloze. *Archeologické rozhledy LXXIII*: 3–47. <https://archeologickerozhledy.cz/index.php/ar/article/view/30/29>
- Smrčka V, Kuželka V, Musilová Z, Gábor O. 2018. Bone diseases at the Lengyel culture burial site in Zengövárkony, Hungary. *Anthropologie LVI*:53–62. <https://doi.org/10.26720/anthro.17.12.12.1>
- Soficaru AD, Ionică C, Constaninescu M, Enyedi M. 2018. Altered shapes, same people: scaphocephaly in the early modern Bucharest. *Homo* 69:176–87. <https://doi.org/10.1016/j.jchb.2018.08.001>

- Steele DG, Bramblett CA. 1988. *The Anatomy and Biology of the Human Skeleton*. College Station: Texas A&M University Press.
- Stuart-Macadam P. 1991. Anaemia in Roman Britain: Poundbury Camp. In: H Bush and M Zvelebil, editors. *Health in Past Societies: Biocultural Interpretations of Human Skeletal Remains in Archaeological Contexts*. Oxford: Tempvs Reparatvm. 101–13.
- Tóth GA, Puskás T, Buda BL. 2009. Co-existence of scaphocephaly and Hand-Schüller-Christian syndrome on the remains of two Neolithic children. *Int J Phys Anthropol & Hum Genet* 28:141–47.
- Ursitti F, Fadda T, Papetti L, Pagnoni M, Nicita F, Iannetti G, Spalice A. 2011. Evaluation and management of nonsyndromic craniosynostosis. *Acta Paediatrica* 100:1185–94. <https://doi.org/10.1111/j.1651-2227.2011.02299>
- Vijay VG, Avadhani R, Jacob M. 2017. Incidence of wormian bones in dry human skulls in south Indian population. *Int J Anat Res* 5:4349–55. <https://doi.org/10.16965/ijar.2017.331>
- Weber J, Collmann H, Czarnetzki A, Spring A, Pusch CM. 2008. Morphometric analysis of untreated adult skulls in syndromic and nonsyndromic craniosynostosis. *Neurosurgical Rev* 31:179–88. <https://doi.org/10.1007/s10143-007-0100>
- White C. 1996. Sutural effects of fronto-occipital cranial modification. *Am J Phys Anthropol* 100:397–410.

