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A Possible Case of Temporomandibular Joint Dislocation, Trepanation, and Metabolic Bone Disease in a Young Adolescent From North-Central Myanmar (1000–700 BCE)

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ABSTRACT

This osteobiography explores the life history of an adolescent who lived during the early-mid Bronze Age (c. 1000–700 BCE) and was buried at Nyaung'gan, a site in north-central Myanmar. Burial 3b had multiple skeletal lesions, and their bones were covered in well-remodeled subperiosteal new bone. A differential diagnosis was undertaken to evaluate the etiology of the lesions and potential co-morbidity. The lesions observed have different underlying mechanisms, and while most represent reactive biological responses to trauma and disease, a circular cranial lesion with remodeled margins is more consistent with intentional trepanation than a natural biological process. The findings suggest that 3b had survived a significant traumatic cranial injury earlier in childhood and was suffering from a dislocated temporomandibular joint and possible co-morbid vitamin D deficiency-related osteomalacia. It is cautiously suggested that 3b survived a subsequent trepanation performed to alleviate symptoms of their condition. Drawing on bioarchaeological approaches to past caregiving, we consider the consequences of these on 3b and how they were cared for, providing unique insight into social dynamics and community care in ancient Myanmar.

1 | Introduction

A bioarchaeology of care approach provides insight into the lived experience of past people, exploring the functional and morphological consequences of injury or disability on an individual, and carefully considers the response of their community (Tilley and Oxenham 2011). Here, we draw on this approach to understand the life history of an adolescent from the Neolithic-Bronze Age site of Nyaung'gan, located in north-central Myanmar (Figure 1) (Pryce et al. 2018).

2 | Biocultural Context

Individual 3b (3b) was buried in a hollowed-out log coffin (Pradier 2022). With 32 small pots, over 100 small, red and large, green semiprecious stone beads, and a bone bracelet, their burial goods were similar to those of other community members buried in the cemetery, although their beads included ones made of unique raw materials and were the most morphologically varied in size and shape (Georjon et al. 2021). Directly above 3b was a primary dog burial and the secondary interment of the skull of a young adult male who was a nonlocal (Bentley et al. 2018). 3b had similar $\delta^{13}C$ and $\delta^{18}O$ values and $^{87}Sr/^{86}Sr$ ratios to those of others from Nyaung'gan, suggesting they grew up in the same area and had a similar diet (Bentley et al. 2018; Willis et al. 2023).

2.1 | Skeletal Documentation

Abnormal variation was observed macroscopically using a 10× hand lens under natural light and an illuminated fluorescent

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FIGURE 1 | Location of Nyaung'gan (black circle) in Myanmar. Scale 500 km. Burial 3b after complete exposure. Scale 100 cm. The frontal bone, left and right forearms, and left lower limb had been removed postmortem, disturbing the bones of the hands and feet, and repositioned above and over the body. The facial bones and the right maxilla were not preserved, but the teeth were unaffected. Map data: Google Earth Pro 2025. Image Landsat/Copernicus Data SIO, NOAA, US Navy, NGA, GEBCO, US Geological Survey. [Colour figure can be viewed at wileyonlinelibrary.com]

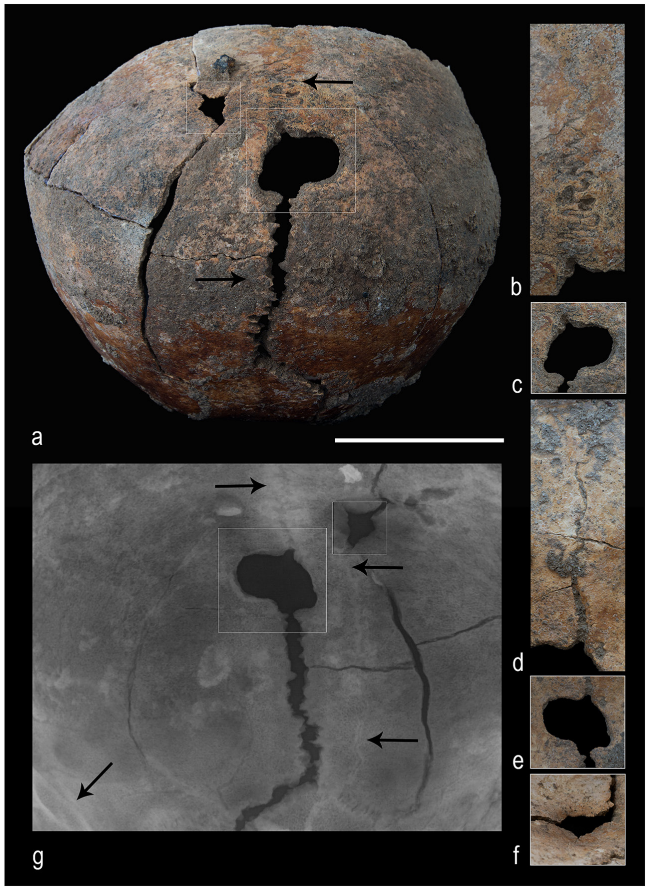

FIGURE 2 | Cranial lesions consistent with trauma and trepanation. (a) Superoposterior aspect of the cranium showing a circular lesion at the midsagittal suture (large square), an asymmetric lesion on the superior left parietal bone (small square), partial synostosis of the anterior sagittal suture, and separation of the posterior sagittal and right lambdoid sutures (arrows). Scale 5 cm. (b) Ectocranial aspect of the anterior sagittal suture. (c) Ectocranial aspect of the circular lesion with remodeled margins and no reactive bone or exposed cranial diploë. (d) Endocranial aspect of the anterior sagittal suture. (e) Endocranial aspect of the circular lesion. (f) Endocranial aspect of the asymmetric lesion with remodeled margins and radiating fractures. (g) Radiograph of endocranial aspect of the cranium highlighting the perisutural radiopacity, cerebral impressions and radiating fracture (arrows), and generalized demineralisation. [Colour figure can be viewed at wileyonlinelibrary.com]

magnifying lamp and recorded in detail. Data were collected in Myanmar in 2016, and only limited options for imaging the remains were available. Radiographs were taken at a private hospital in Mandalay.

3 | Results

3.1 | Biological Profile

Tooth formation and eruption indicated that 3b was approximately 14.5 years of age (AlQahtani et al. 2010). The dentition was well-preserved with no evidence of carious lesions, antemortem tooth loss, periapical lesions, or linear enamel hypoplasia.

3.2 | Lesion Description

Macroscopic and radiographic analyses revealed multiple skeletal lesions. The cranium of 3b was an unusual shape, with a flattened occipital bone, and the anterior sagittal suture appeared less serrated than expected for an adolescent. Mild cerebral impressions were evident on the left and right parietal bones. A large circular lesion and an asymmetric depressed lesion were observed on the cranium (Figure 2a–f). Thin subperiosteal new bone covered the temporal bones. Contralateral differences in the insertion sites for the muscles associated with chewing and diffuse red staining on the anterior dentition were observed on the mandible (Figure 3a–h). Cavitating lesions were present within the proximal metaphyses of the humeri with poorly mineralized new bone overlying the lesion on the left humerus. Radiographs revealed that the underlying lesions had well-defined sclerotic margins, indicating a benign etiology. Bilaterally, there was subtle curvature of the shafts of the humeri and femora and widening of the metaphyses of the humeri distally and the femora proximally. Smooth plaque-like subperiosteal new bone with longitudinal striations covered the long bones (Figure 4a–h).

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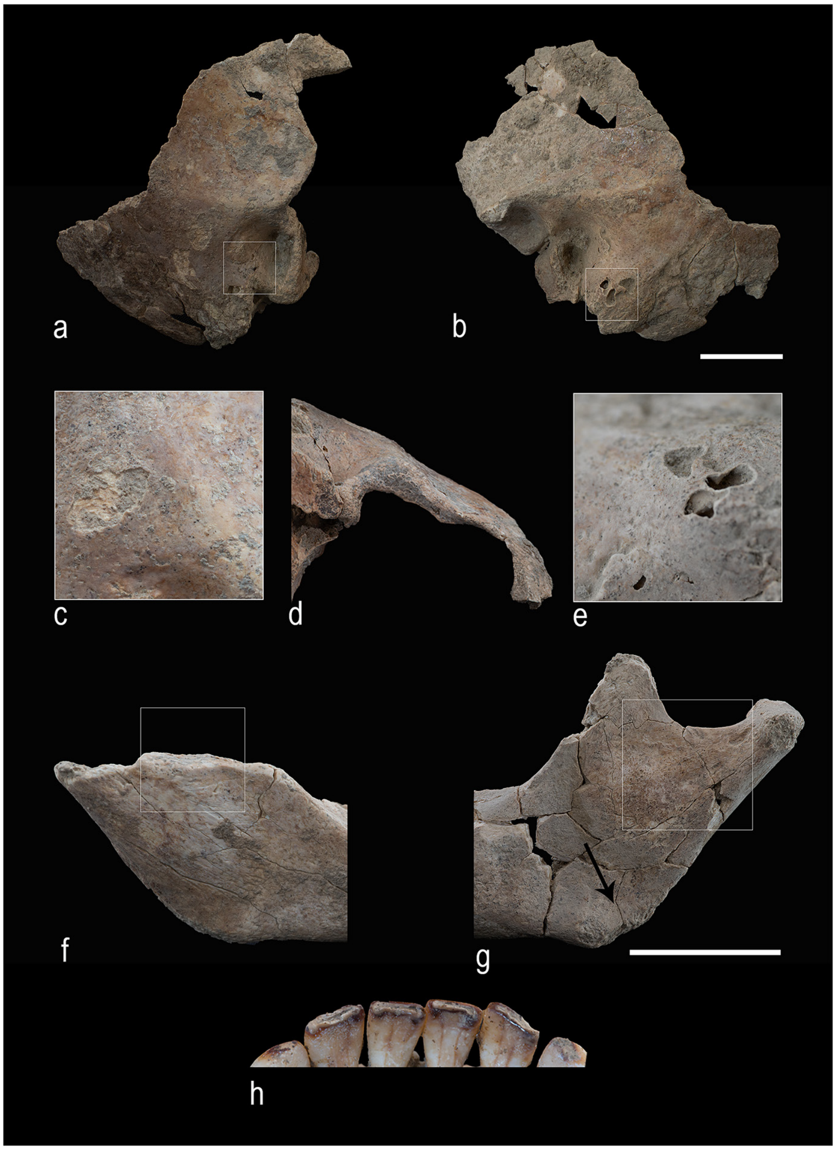

FIGURE 3 | Skeletal lesions consistent with chronic masticatory adaptation. Lateral aspect of the right (a) and left (b) temporal bones showing thin subperiosteal new bone and fistulae. Scale 2 cm. (c) Detail of thin subperiosteal new bone ~1 mm thick. (d) Inferior aspect of the right temporal bone. (e) Detail of smooth-walled fistulae. Lateral aspect of the right (f) and left (g) ramus of the mandible showing an accentuated insertion site for the masseter muscle on the left gonial region in comparison to the opposite side (arrow). Scale 2 cm. (h) Diffuse red staining on the anterior dentition concentrated on the occlusal surfaces. Squares show reactive bone detailed in Figure 5. [Colour figure can be viewed at wileyonlinelibrary.com]

The lesions observed have different underlying mechanisms and represent reactive biological responses to both trauma and disease. The most significant were the cranial lesions, the subperiosteal new bone, and decreased bone density. The ambiguity and nonspecific nature of these lesions posed a significant challenge. Focus was placed on the potential causal relationships between the lesions. The cranial lesions likely had different underlying etiologies, possibly infection, trauma, or trepanation, based on their position and morphology (Barnes 2012; Kaufman et al. 1997; Verano 2017). Radiographically, the periosteal reaction was indistinct from the underlying cortices, indicating that the subperiosteal new bone was well-remodeled, which could indicate a biological healing response to a chronic systemic inflammatory condition, mechanical weakness from osteolysis, isolation of a tumor, or an alteration to circulation—passive hyperaemia (Ragsdale et al. 2017).

4 | Discussion

Based on the lesions observed, we focused on infectious and metabolic conditions, but trauma, trepanation, and co-morbidity were also considered.

Among children, both treponemal disease and tuberculosis can cause destructive cranial and postcranial lesions. Thick, plaque-like, nongummatous periosteal new bone can form in patients with treponemal disease, but it is normally localized and under major overlying muscles (Ortner 2003), which does not match the pattern observed in this case. No evidence of gumma on the long bones or nodes of expansion with focal superficial cavitation was observed, and the cranial lesions were not consistent with gummatous *caries sicca* (Vlok et al. 2020). Morphologically, the larger cranial lesion is similar to cranial tuberculosis (Spekker

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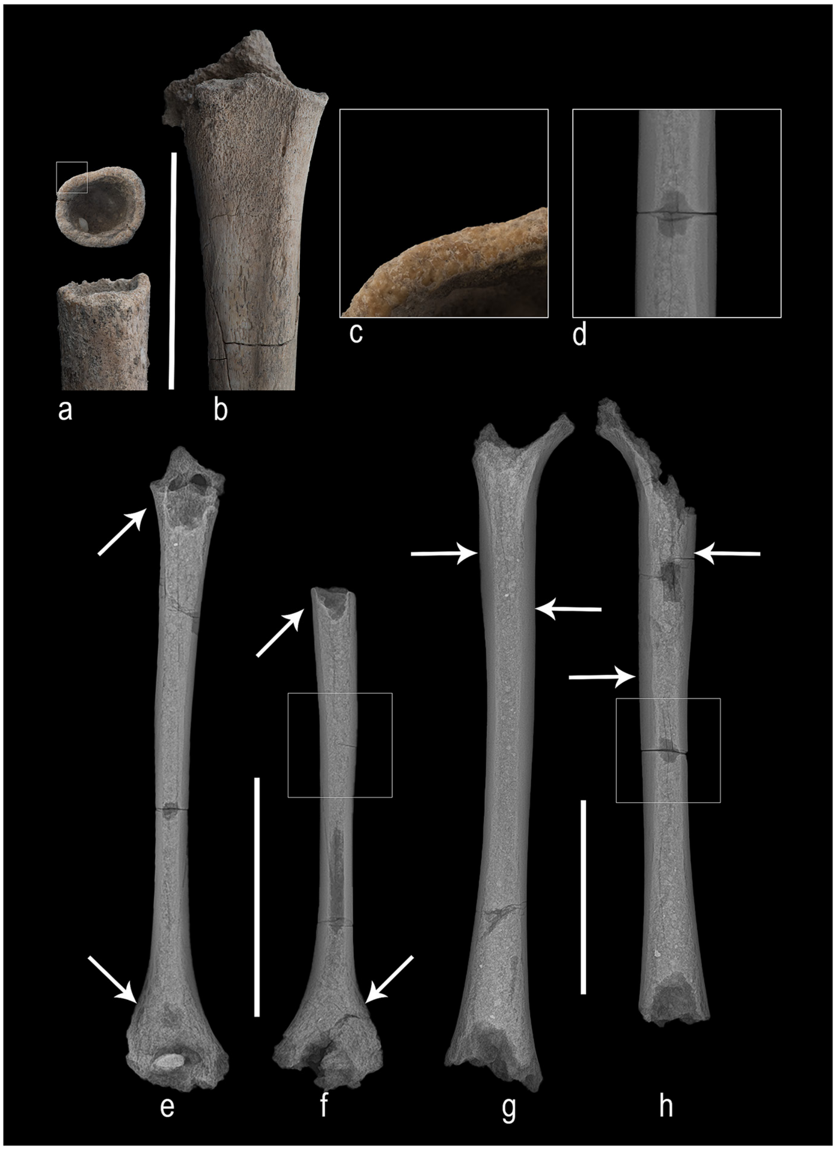

FIGURE 4 | Skeletal lesions consistent with poorly mineralized bone. Anterior aspect of the proximal right (a) and left (b) humerus showing reactive new bone and remodeled bone. Scale 5 cm. (c) Detail of remodeled cortical margin (small square). (d) Detail of the medial aspect of the right femur showing chronic periosteal reaction (large square). Radiograph of the posterior aspects of the left (e) and right (f) humerus showing cavitating lesions in the proximal metaphyseal region with sclerotic margins (arrows), overlaid with poorly mineralized new bone, and metaphyseal expansion with radiolucent intracortical foci distally (arrows). Radiograph of the posterior aspect of the left (g) and right (h) femur showing cortical expansion and widening of the proximal metaphyseal region (arrows), blurring of the cortico-medullary margin (arrows), and radiolucent intracortical foci distally. Squares show possible cortical insufficiency fractures. Scales 10 cm. [Colour figure can be viewed at wileyonlinelibrary.com]

et al. 2022), but there were no endocranial vascular changes, and inflammatory subperiosteal new bone is not commonly observed in tuberculosis.

Responsible for the transportation of calcium into the blood, vitamin D is essential for maintaining adequate bone health and biomechanical strength. Caused by malabsorption or inadequate vitamin D, rickets and osteomalacia share the same etiology with different age-related skeletal lesions, and lesions of both can coexist before epiphyseal fusion (Brickley et al. 2014, 53; Resnick et al. 2024, 589). Rickets is characterized by ineffective mineralization of the growth plates affecting endochondral growth, while osteomalacia is characterized by ineffective mineralization of newly accumulated osteoid bone affecting mature cortical and trabecular bone quality and maintenance (Brickley and Morgan 2023; Vlok et al. 2024). The craniotabes, biomechanical bending stress, poorly mineralized metaphyseal cortical bone, subtle curvature and widening of the proximal femoral metaphyses, and possible cortical insufficiency fractures are typical of vitamin D deficiency.

Secondary hyperparathyroidism is usually present in cases of vitamin D deficiency, which causes hypocalcaemia and stimulates excess secretion of parathyroid hormone (Brickley et al. 2020, 113). In response, osteoclastic activity and bone resorption are stimulated, releasing minerals stored in bone and increasing blood calcium levels (Uday and Högler 2017). As a reparative response to rapid bone resorption, proliferating vascular fibrous tissue can replace bone marrow,

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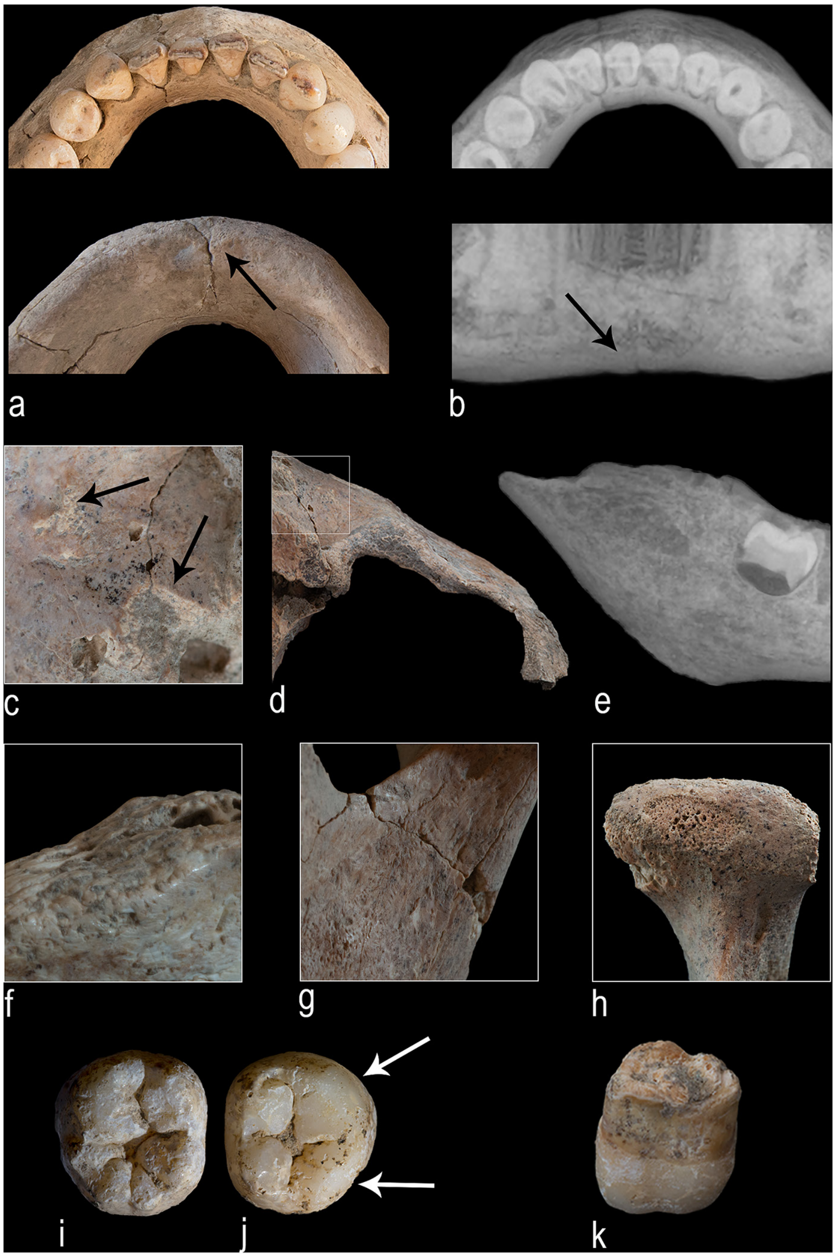

FIGURE 5 | Skeletal lesions consistent with chronic malocclusion. Superior and inferior aspects of the mandible showing reactive bone and possible trauma. (a) Reactive bone and possible healing fracture (arrow). (b) Radiographs showing the same features. (c) Detail of right temporal bone showing reactive bone and abrasion lesion (arrows, small square, Figure 3a). (d) Inferior aspect with exposed diploë. (e) Radiograph showing sclerosis on the margin of the right ascending ramus. (f) Detail of well-organized, reactive cortical bone (small square, Figure 3f). (g) Detail of reactive bone on the left ascending ramus (large square, Figure 3g). (h) Anterior aspect of the left mandibular condyle with a circumscribed oval-shaped area of porosity. Comparison of left (i) and right (j) mandibular second molars showing differential wear pattern on the occlusal surface (arrows). (k) Malformation of the roots of the right maxillary second molar. [Colour figure can be viewed at wileyonlinelibrary.com]

appearing as cyst-like, nonneoplastic brown tumors (Karaca et al. 2024), which can cause severe disfigurement (Jaouahar et al. 2025). Brown tumors may be well-defined, with or without a sclerotic rim, multilobulated or unilobulated, expansile or nonexpansile, and involve cortical or trabecular bone with little reactive change in adjacent bone (Bennett et al. 2020). Normally confined, they can breach the cortex (Mansfield and Raal 2022), and where the expanding tumor compromises the structural integrity of the bone, pathological fractures are common (Vanitcharoenkul et al. 2021). Among infants and children with hyperparathyroidism, resorption and lesions can be severe with metaphyseal destruction and periostitis that can mimic syphilitic infection (Resnick et al. 2024, 605). The lesions in the proximal humeri with well-defined radiographic sclerotic margins, and the syphilitic-like periostitis are consistent with secondary hyperparathyroidism, which frequently co-occurs with rickets and osteomalacia (Resnick et al. 2024, 590).

Among the pathological lesions observed, the expanded contours of bones indicating marrow hyperplasia, cortico-medullary reticulation of the internal trabecular structure of

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the scapulae, shape of the cranium with secondary craniosynostosis and radiolucent intracortical foci suggest that 3b may have had thalassemia, which can cause significant osteopenia and vitamin D deficiency (Lagia et al. 2007; Monge Calleja et al. 2024; Vlok et al. 2021). The lesions in the proximal humeri are consistent with infarction or osteonecrosis commonly associated with thalassemia (Kanthawang et al. 2016; Karantanas 2023).

A significant complication of these conditions is spontaneous fracture and increased vulnerability to traumatic injury. The asymmetric cranial lesion on 3b's cranium is consistent with a healed depressed comminuted fracture, where an isolated fragment of bone has necrosed and resorbed (Verano 2017). While osteolytic cranial lesions have been observed in patients with thalassemia and hyperparathyroidism, they do not normally cross the suture line (Diacinti et al. 2021; Orzincolo et al. 1988). The larger lesion is consistent with a leptomeningeal cyst and diastatic fracture propagating toward the cranial base (Arora and Vani 2023; Love et al. 2011), but the unnatural morphology of the lesion is not consistent with a natural biological process. The radiographically sclerotic margin and lack of exposed diploë are more consistent with an intentional trepanation that has healed (Andrushko and Verano 2008; Smrčka et al. 2003).

As the origin and insertion sites of the temporalis muscle, any significant alteration to the temporal bone or coronoid process would have functional implications for chewing, potentially explaining the contralateral differences in the insertion sites of the left masseter and right pterygoid muscles, which were accentuated compared with the opposite side. These asymmetric changes, the well-organized, reactive cortical bone on the right and left mandibular ramus, and the bone loss on the left mandibular condyle suggest chronic malocclusion and masticatory adaptation to an event or condition that occurred or developed before the age of 10.5–11.5 years, affecting the development of the maxillary molar roots. Based on the lesions observed, a superolateral dislocation of the right mandibular condyle and fracture of the coronoid process and mandibular body are most probable (Seok et al. 2022). Although rare, the reactive bone and the corresponding lesions from mechanical abrasion (Figure 5a–k) and the position in which 3b lay support this diagnosis.

4.1 | Limitations of the Study

Due to the poor preservation of 3b, a diagnosis was not possible. Because pathological foci with reduced structural integrity are vulnerable to postmortem taphonomic alteration and poor preservation, and identifying underlying lesions is often not possible, conditions with destructive lesions are likely underdiagnosed and underreported. Cases of co-morbidity are diagnostically challenging, and many lesions associated with metabolic, endocrine, and haemolytic conditions are subtle, overlapping, or assessed radiographically. The preservation of the remains and concretion obscuring the bone surfaces severely limited our observations and ability to refine our diagnosis. We remain cautious in our findings and conscious that alternative interpretations are possible.

5 | Conclusion

This osteobiography explored the life of 3b, who lived in a small village in Myanmar sometime between 1000 and 700 BCE. Their story reflects one of resilience and perseverance. The differential diagnosis strongly suggests that trepanation was performed on 3b. It is not possible to establish when it occurred, but it was healed, suggesting 3b survived at least several months, if not years (Nerlich et al. 2003). Whether the trepanation was undertaken as a medical intervention to alleviate intracranial pressure caused by partial premature craniosynostosis or to alleviate swelling from a haematoma caused by cranial trauma is not possible to infer. What can be inferred is the intentional choice of the community to undertake a medical intervention, the skill, proficiency, and knowledge of the physician who performed the procedure, and the care and compassion of the carers who looked after 3b.

There were no signs of growth deficits or evidence of nonspecific indicators of childhood stress, indicating that 3b was well cared for and received adequate nutrition to support normal development. Sadly, they passed away around 14.5 years of age. The evidence suggests that 3b had survived significant cranial trauma earlier in childhood, likely also affecting their mandible, and was suffering from a metabolic disorder. If 3b experienced a traumatic injury or suffered illness and were bedridden for an extended period and unable to go outdoors, they may have developed vitamin D deficiency. Their life experiences would have affected their ability to perform essential daily self-maintenance, requiring ongoing healthcare. *Areca catechu*, a traditional medicine known in the region for its stimulant and narcotic effects and for staining teeth red (Department of Traditional Medicine 2000), could have been given to 3b to help relieve pain.

Assuming the interpretation of trepanation is correct, such a surgical procedure speaks to the profound ingenuity of this community in ancient Myanmar. It suggests that they knew of intracranial pressure and how to relieve it. That 3b survived the procedure indicates they had knowledge and skills in aftercare, how to mitigate infection, and administer appropriate pain relief. The number and exotic nature of the mortuary offerings interred with 3b indicate their special place within the community, while the dog buried with 3b may reflect the community's emotive and protective nature toward them even after death.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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