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Technical note

Use of high resolution computed tomography to diagnose ante-mortem dental root fractures in archaeological samples

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ABSTRACT

Dental root fractures are rarely documented in past human populations, but when they are observed, diagnosing ante-mortem events as causal factors can be difficult due to postmortem alteration. Can high resolution X-ray computed tomography (CT) improve our ability to diagnose if a dental fracture was caused ante- or post-mortem? To test this, a case study of two individuals with previously diagnosed dental root fractures were re-examined with high resolution CT to confirm or refute the original diagnoses. For individual 4170, use of high resolution CT supported the original diagnosis of an ante-mortem root fracture on the right mandibular central incisor that was made based on planar X-ray. With the new analyses, the root fracture was found to be associated with evidence of calcification, and with radicular and alveolar bone resorption, which are positive correlates of an ante-mortem origin. Resolving this level of detail of bone modification was not possible without using high resolution CT. For individual 4172, the use of high resolution CT enabled visualisation of fracturing and cracking throughout several molars and crowns of other teeth that were not evident in planar X-ray, suggesting that these fractures were likely produced by post-mortem taphonomic processes rather than ante-mortem events as originally diagnosed. In this case study, high resolution CT offered critical advantages compared to a planar X-ray approach, such as using 3D multiple slice views without superimposing alveolar bone and teeth as in planar X-ray imaging. This study demonstrates the potential of high resolution CT in confirming and refuting ante-mortem processes, and that visualisation of 3D structures is crucial for arriving at definitive diagnoses.

1. Introduction

When assessing incidence and prevalence of dental pathology in an archaeological assemblage, it has been shown that planar X-ray should be used to ensure the full extent of dental pathology is observed (Lucas et al., 2010; Gibbon and Grimoud, 2014). With most dental practitioners using digital radiography, this method is affordable and easily accessible. Gibbon and Grimoud (2014) employed planar X-ray to investigate an Iron Age assemblage from Ingombe Ilede in Zambia (Fig. 1). Wherein, two individuals (4170 and 4172) with horizontal dental root fractures were discovered without any morphological evidence of their existence on the surface. Horizontal root fractures are particularly rare among living people (Öztan and Sonat, 2001). When they occur, they are most commonly found in anterior teeth (Çalişkan and Pehlivan, 1996), and caused by trauma or heavy mastication (fatigue fractures) (Yeh, 1997; Bastone et al., 2000). Studies have shown that living with an asymptomatic horizontal root fracture is possible, and that the tooth has a good chance of survival (Öztan and Sonat, 2001; Çobankara and Üngör,2007).

As these fractures are rare, even in living people, they are uncommon in archaeological contexts. This is because few studies employ non-destructive imaging techniques, such as planar X-ray, and more rarely high resolution CT. In addition, taphonomic processes in archaeologically-derived remains generate similar changes in bone and teeth to ante-mortem traumatic events (Fernández-Jalvo et al., 2002). When a fracture is observed, a challenge of working with archaeologically-derived remains is to distinguish the fracture as the result of an ante-mortem event. Diagnosis of a dental fracture with planar X-rays

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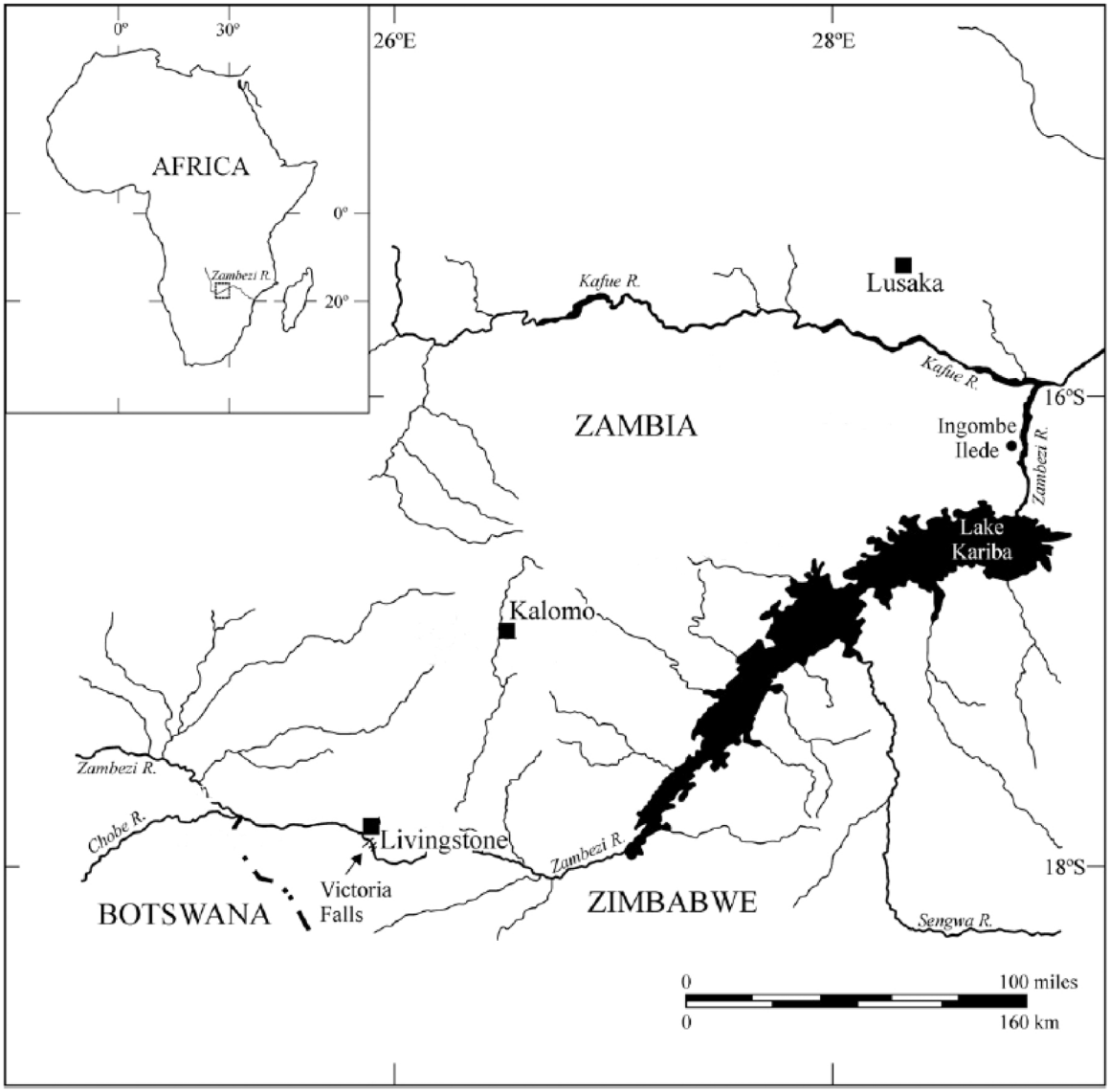

Fig. 1. The location of Ingombe Ilede, the stratified Iron Age site located in Zambia (modified from Huffman 2010, pp. 2578).

in this type of dataset is based on direct visualisation of a radiolucent line traversing the root and/or the crown (White and Pharoah, 2014). Specifically, in archaeological samples two criteria are traditionally used to identify an ante-mortem fracture: the tooth should be retained in the jaw (Lukacs and Hemphill, 1990), and survival of the pulp should be determined by absence of tooth discoloration (Hillson, 2005; Andreasen and Kahler, 2015). However, neither of these are terribly accurate, as retention in the jaw and changes in colouration occur on a continuum, or not at all. Therefore, establishing additional indicators may help improve the accuracy of these diagnoses.

An ante-mortem fracture diagnosis in an archaeological sample is only meaningful if we can conclusively distinguish it from a post-mortem event. The concerns raised above regarding accuracy of an ante-mortem diagnosis using planar X-ray point to whether the application of better visualisation technology would improve our ability to diagnose if a dental fracture was caused ante- or post-mortem. To test this, we apply high resolution X-ray computed tomography (CT) to re-evaluate previously diagnosed ante-mortem fractures in two individuals from an Iron Age archaeological sample. The original diagnoses based on planar X-rays included ante-mortem horizontal root fractures involving the dentine, cementum and pulp (Gibbon and Grimoud, 2014). We reassess the accuracy of these diagnoses using high resolution CT to extract additional information beyond what was extracted using planar X-ray. This application is an opportunity to evaluate new potential for high resolution CT.

2. Materials and methods

Two individuals from Ingombe Ilede, an Iron Age archaeological site located in Zambia (Fig. 1) (Huffman, 1989, 2010), were used in this study. This site is dated to the Late Iron Age period in the 15th century (Fagan et al., 1969; Huffman, 1989; Gibbon et al., 2014). The site was excavated between 1959 and 1965 by Fagan et al. (1969). Individual 4170 (burial II 4) is estimated to be a 20–24-year-old male, with a previously diagnosed horizontal root fracture in the right mandibular 1st incisor. Individual 4172 (burial II 7) is estimated to be a 24–40-year-old female, with a previously diagnosed horizontal root fracture in the middle third of the root of the right second molar (Gibbon and Grimoud, 2014). Both individuals are stored in 'The Raymond A. Dart Collection of Human Skeletons', School of Anatomical Sciences at the University of the Witwatersrand, South Africa (ethical clearance W-CJ-140604-1). The site is famous for several rich burials containing gold beads, copper crosses and iron bells, and was discovered when the Water Department constructed a large water tank on a ridge near the