Root grooves on two adjacent anterior teeth of *Australopithecus africanus*

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Number of pages: 12
Number of figures: 3
Number of tables: 1
Abbreviated title: *Australopithecus* tooth grooves

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Abstract

Tooth root grooves and other ante-mortem dental tissue loss not associated with caries found on or near the cementoenamel junction (CEJ) are commonly termed non-carious cervical lesions. Three main processes are implicated in forming these lesions: abrasion, dental erosion, and abfraction. As yet, these lesions have not been described in non-*Homo* hominins. In this study South African fossil hominin collections were examined for evidence of any type of non-carious cervical lesion. Only one individual shows ante-mortem root grooves consistent with non-carious cervical lesions. Two teeth, a mandibular right permanent lateral incisor (STW 270) and canine (STW 213), belonging to the same *Australopithecus africanus* individual, show clear ante-mortem grooves on the labial root surface. These lesions start below the CEJ, extend over a third of the way toward the apex, and taper to a point towards the lingual side. The characteristics of these grooves suggest the predominant aetiology was erosive wear. In addition, they are extremely similar to clinical examples of dental erosion. These are the oldest hominin examples of non-carious cervical lesions and first described in a genus other than *Homo*; further, the lesions suggest that this individual regularly processed and consumed acidic food items.

Key words
Dental erosion; tooth wear; hominin diet; *Australopithecus africanus*; acidic food

1. Introduction

Non-carious cervical lesions (NCCLs), resulting from the loss of dental tissue at or near the cementoenamel junction (CEJ), are not uncommon in the dentitions of recent human populations (Levitch et al., 1994; Wood et al., 2008; Grippo et al., 2012). They may result from several processes, the most common of which are abrasion, dental erosion and abfraction (Litonjua et al., 2003; Michael et al., 2009). As such, when NCCLs are present in archaeological and, in this case, fossil hominin remains, they may provide insight into diet and behaviour.

Abrasion is the most common mechanism of NCCLs observed in archaeological samples; it results from non-masticatory contact of an object with the teeth, and commonly relates to cultural or therapeutic behaviour (e.g., Turner and Cacciatore, 1998; Ungar et al., 2001; Novak, 2015; Estalrrich et al., 2016). All NCCLs in fossil examples are currently attributed to abrasion and reported only in members of the genus *Homo*. The majority of these abrasion NCCLs are considered to be 'toothpick grooves' (Ubelaker et al., 1969; Boaz and Howell, 1977; Frayer and Russell, 1987; Brown and Molnar, 1990; Milner and Larsen, 1991; Bermudez de Castro et al., 1997; Turner and Cacciatore, 1998; Ungar et al., 2001; Hlusko, 2003; Bouchneb and Maureille, 2004; Kaidonis et al., 2012; Lozano et al., 2013; Tillier et al., 2013; Ricci et al., 2014; Sun et al., 2014; Frayer et al., 2017). Anterior teeth can be affected, but most of these grooves are present in the interproximal areas of the premolars and molars (Formicola, 1988; Frayer, 1991; Ungar et al., 2001), with buccolingual micro-striations often evident (Bouchneb and Maureille, 2004; Grine et al., 2000; Hlusko, 2003; Lozano et al., 2013; Estalrrich et al., 2016; Sun et al., 2014). The enamel, dentine, and/or cementum are affected depending on groove depth and location, i.e., above, below or directly on the CEJ. The cause of these abrasive grooves is debated but the growing consensus is the use of a sort of toothpick, in which an item was deliberately placed regularly in certain locations, either to dislodge food or attempt to reduce pain (Formicola, 1988; Ungar et al., 2001; Martinón-Torres et al., 2011; Lozano et al., 2013). Given the occurrence of such grooves in diverse populations, it is likely that a variety of instruments was used in forming these lesions (Frayer et al., 2017). Some, but not all, grooves are associated with dental pathology, including periodontal disease and caries. Other processes have also been suggested, including fiber processing and saliva jetting (Brown and Molnar, 1990; Eckhardt, 1990; Wallace, 1974).

Dental corrosion, or erosion as it is more commonly called, has been extensively researched in modern (e.g., Zero, 1996; Aubry et al., 2003; Oginni et al., 2003; Grippo et al., 2004) and archaeological human dentitions (e.g., Robb et al., 1991; Indriati and Buikstra, 2001; Ritter et al., 2009; Watson and Haas, 2017). It occurs through the chemical dissolution of dental tissues by acids of non-bacterial origin and can be caused by a range of factors, most notably low pH diets (Indriati and Buikstra, 2001; Oginni et al., 2003; Ritter et al., 2009; Watson and Haas, 2017). Endogenous factors can also create erosive lesions, including gastroesophageal reflux disorder and eating disorders (Loomba et al., 2013; Milosevic et al., 1997).

Additionally, conditions that reduce the rate of saliva secretion can also lead to an increased chance of dental erosion (El-Marakby et al., 2017). Typically, endogenous acids create lingual lesions on anterior teeth whereas those associated with diet or non-masticatory activities commonly affect the labial surface (Loomba et al., 2013).

Abfraction is the term used to describe tissue breakdown in the cervical region of teeth from extreme or unusual occlusal loading from mastication, bruxism, or malocclusion (Lee and Eakle, 1984; Grippo, 1991; Grippo et al., 2012). This process is subject to debate, especially in archaeological specimens (Aubry et al., 2003; Michael et al., 2009; Urzúa et al., 2015; Hur et al., 2011). The reason is the lack of conclusive evidence that such processes could strongly influence NCCLs formation, with a lack of attributable lesions in pre-modern specimens. It is therefore possible that the web-shaped NCCLs lesions associated with abfraction may relate only to modern dental practices or diet (El-Marakby et al., 2017).

The position and shape of NCCLs can give insight into their aetiology. In particular, by comparing specimens with clinical examples it is possible to infer possible aetiologies in archaeological specimens. However, as evidenced in clinical studies NCCLs may have multifactorial origins, though the dominant factor will often create unique characteristics (Marinescu et al., 2017). Abrafaction is characterised by wedged shaped lesions that usually affect the labial/buccal surface (Grippo et al., 2012). Abrasive wear is also often distinctive, with non-symmetric lesions that commonly show directional striations (Sun et al., 2014). Abrasive NCCLs are typically V-shaped, and in severe cases can take on a wedge appearance that superficially may resemble abfraction lesions (Loomba et al., 2013). Erosive NCCLs may also be non-symmetric, and typically yield shallow, smooth surfaces (Wood et al., 2008; Levitch et al., 1994). Abrasion and erosion together can lead to an increased likelihood and/or severity of lesions; most causes of erosive NCCLs will be influenced by abrasion, at least to some extent. Erosion weakens dental material, allowing even minimal abrasion to create extensive, further wear (Wu et al., 2017). The underlying dentine associated with erosion and abrasion in NCCLs is shiny, with the lesions more similar in appearance to the surrounding dentine in erosive cases than abrasive (Bader et al., 1993).

No NCCLs, to date, have been detailed in South African fossil hominins–*Homo* or otherwise (Wallace, 1974; Ungar et al., 2001). For this report, we re-examined the South African collections for evidence of any NCCL type, in specimens assigned to *Paranthropus robustus*, *Australopithecus africanus*, *A. sediba*, *Homo naledi*, and early *Homo* (sensu lato). Of these, one individual is affected. The aetiology is discussed below and a differential diagnosis conducted.

2. Materials and Methods

The teeth in this study include a mandibular right permanent lateral incisor, STW 270, and a mandibular right permanent canine plus several other teeth collectively assigned to STW 213; all are thought to belong to the same individual (Moggi-Cecchi et al., 2006). The other, unaffected teeth from this individual are the mandibular first and second molars, premolars and left canine. These specimens originate from Sterkfontein Member 4 and date to 2.8–2.4 Ma (Pickering et al., 2004). Although many consider material from Member 4 to belong to *A. africanus*, others suggest multiple species may be present (e.g., Calcagno et al., 1999; Lockwood and Tobias, 1999; Wood and Richmond, 2000; Moggi-Cecchi, 2003; Grine et al., 2013; Fornai et al., 2015). That said, the specimens studied here are routinely described as *A. africanus*. The only prior mention of the antemortem grooves described here is from Moggi-Cecchi et al. (2006), where they were used to associate STW 270 with 213.

In this study, the teeth were first examined macroscopically, followed by microscopic observations using a Leica© DMS300 digital microscope (variable magnification ranging from 15 to 40X). Signs of postmortem damage, other pathology, wear and/or developmental defects on the teeth were also recorded and are described. Data were collected at the University of the Witwatersrandand and the Ditsong Museum of South Africa.

3. Results

STW 270 exhibits wear on the incisal edge with a strip of exposed dentine (wear grade 4; Smith, 1984), suggesting that the tooth was in occlusion for some time. An antemortem, concave depression, i.e., shallow groove is evident on the labial root surface just below the CEJ, which extends more than one third of the way toward the apex (Figure 1A). Microscopic examination revealed no directional antemortem striations (Figure 1B). The groove spreads around to the interproximal areas of the root, narrowing to a point towards the lingual side (Figure 2). The process that created the groove does not appear to have affected other dental tissues, although slight postmortem damage towards the CEJ on the labial surface may mask some evidence. Comparisons with other *A. africanus* teeth show that this is clearly not a morphological feature.

Figure 1. STW 270 (*A. africanus*) right mandibular lateral incisor. A) Bottom row from left to right: lingual, labial, mesial, and distal. White arrows and square highlight the location of the groove. The white bar is 1 cm long. B) Close-up of the groove (white square in A), showing no directional striations and a smooth surface.

Figure 2. STW 270 (*A. africanus*) right mandibular lateral incisor. Distal side, showing the root groove tapering toward the lingual surface.

A smaller depression/shallow groove is visible in the same position on the root of the adjacent canine, STW 213 (Figure 3). However, this tooth has greater post-mortem damage than STW 270 so the full extent of the groove is more difficult to interpret. The shape appears comparable, and grooves in both teeth originate just below the CEJ and extend 5-6 mm down the root. The NCCL on the canine is not as deep as that on the incisor, but given the location and similarity in appearance it is likely that both share a common aetiology.

Figure 3. STW 213, mandibular right canine. Left to right: mesial, distal, labial, lingual; upper right: root tip; lower right: crown top.

The other STW 213 teeth do not have root grooves (all mandibular teeth: first and second molars, premolars and left canine). Clear deep furrows are present on the enamel of the right premolars and right canine that are thought to be linear enamel hypoplasia (Guatelli-Steinberg, 2003). The left premolars show no enamel defects. Therefore, the enamel furrows on the right teeth are either not systemic hypoplastic defects, or more than one individual is represented in STW 213. It is possible therefore that the enamel grooves may relate to erosive wear, however further comparative studies are needed. There is no evidence of caries or calculus. No other NCCLs are found on the other South African fossil hominins studied (Table 1).

Table Error! No text of specified style in document.**.1. Number of permanent teeth for each fossil hominin species studied showing non-carious cervical lesions (NCCLs).**

Species	Observable Teeth	# NCCLs	% NCCLs
H. naledi	147	0	0
A. sediba	16	0	0
P. robustus	318	0	0
A. africanus	328	2	0.61%
Early *Homo*	44	0	0

4. Differential diagnosis

The STW 270 NCCL appears superficially similar to one described by Novak (2015) in an historic example, i.e., shallow labial groove on a lower canine that extends one third of the way down the root from the CEJ and thought to result from habitual abrasion. However, the shallow grooves of the *A. africanus* teeth that wrap uniformly around both incisor and canine from the labial surface, tapering into the interproximal areas, suggest a different aetiology. The STW 270 lesion is also clearly different from typical toothpick grooves associated with specimens of *Homo* (e.g., Frayer and Russell, 1987; Ungar et al., 2001; Lozano et al., 2013; Sun et al., 2014; Tillier et al., 2013; Frayer et al., 2017). Evidence for abfraction-caused NCCLs is limited, but the shallow grooves in STW 270 and 213 do not have the representative wedge shape said to be associated with this process (Michael et al., 2009; Grippo et al., 2012).

Instead, the *A. africanus* grooves best fit a predominant aetiology of erosion, since the lesions are shallow with an obtuse angle, have smooth surfaces, and little difference in appearance is evident between the lesion and surrounding tissue (Loomba et al., 2013; Bader et al., 1993; Wood et al., 2008; Levitch et al., 1994). Furthermore, they appear indistinguishable from examples of dental erosion in clinical studies. For example, Bader et al. (1993) highlight a case that also presents a depression/shallow groove on the labial root surface that tapers to a point toward the interproximal areas–along the gingival margins. Additionally, Grippo et al. (2012) describe an upper canine with the erosive lesion extending a significant way down the labial surface of the exposed root. The way in which the shallow groove on the *A. africanus* teeth wrap around the root from the labial surface may suggest that they also followed the gingival margins, which is more indicative of erosion. Further, the depressions vary in width but, again, are smooth/uniform as they taper into the interproximal surfaces, which is also suggestive of erosion (Aubry et al., 2003). Therefore, based on the current understanding of NCCLs all signs for STW 270 and 213 suggest the most influential process involved in their formation was erosive wear.

A gastric origin for the acid can likely be discounted, since the lingual tooth surfaces are usually affected, as well as posterior teeth (Loch et al., 2013; Loomba et al., 2013). More likely the cause is diet-related. Indeed, it is common for acidic diets to cause NCCLs in the positions affected. Raw food diets have also been shown to increase the risk of NCCLs (Addy and Shellis, 2006; Ganss et al., 1999), suggesting that citrus fruit and/or other acidic foods can be the cause. Ritter et al. (2009) report similar NCCLs in archaeological groups that consumed citrus fruits. Another archaeological example described by Watson and Haas (2017; see their Fig. 7) is akin to that described herein. Shallow labial depressions/grooves are present on some roots of anterior mandibular teeth in a group of foragers, though in association with LSAMAT, i.e., lingual surface attrition of the maxillary anterior teeth (Irish and Turner, 1987, 1997). This finding led Watson and Haas (2017) to suggest oral processing of tubers yielded both types of lesions. Tubers are variably acidic, and gingival and alveolar recession may result from stripping and consuming them in a raw state. The present NCCLs could have resulted from such a process, where acidic fruit/plant or other food items were 'processed' in the mouth, or otherwise placed in contact with the anterior teeth for long enough periods to erode dentine. Support is provided by research showing that abrasion and erosion acting together can lead to more severe lesions (Eisenburger et al., 2003). Therefore, the aetiology of these lesions, like the majority of NCCLs, is likely multi-factorial; however, characteristics of the lesions suggest that erosion was the most influential factor.

In sum, this is the oldest fossil hominin example of NCCLs, and the first described in a genus other than *Homo*. The characteristics of the shallow root grooves on the STW 270 incisor and 213 canine are identical to examples of dental erosion in the clinical and archaeological literature. That said, their apparent uniqueness does little to help us to understand the diet or behaviour of *A. africanus*; however, these grooves do serve to attribute some individuality to this particular *A. africanus* individual.

Acknowledgements

We thank B. Zipfel for access to the collections at the University of the Witwatersrand and S. Potze from the Ditsong Museum of South Africa for access to their collections. We would also like to thank J. Moggi-Cecchi, D. Guatelli-Steinberg and M. Novak for assistance and advice during this project. This research was supported by a studentship to the first author from Liverpool John Moores University.