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ABSTRACT

Objectives: In many hunter-gatherer populations the teeth are used as a third hand or a tool. Much attention has been paid to wear and its relationship to gendered division of labor, but age is also a significant organizing factor in many societies. In this paper, I analyze whether the pattern of wear at Roonka, Australia, reflects the age-graded acquisition of tasks.

Materials and Methods: The remains analyzed come from Roonka and date from c6000 BP to 150 BP. In total 126 adults and juveniles were analyzed. Wear gradients were calculated for each tooth relative to wear on the first molar. Data were compared using non-parametric statistics and cluster analysis to assess the degree of patterning within the sample.

Results: Dental wear proceeded rapidly. There is no evidence of sex differences in the pattern of wear. Age differences do occur. While disproportionate anterior wear occurs among juveniles and young adults, by middle adulthood the pattern is less variable and involves the premolars. Old adults have a much flatter pattern of wear.

Discussion: The pattern of wear is consistent with ethnographic observations which suggest a degree of latitude in the activities of juveniles and young adults. By middle age variability between individuals declines reflecting shared tasks and more intensive use of the teeth. The pattern of wear amongst old adults, however, is much flatter presumably due to changes in occlusion. While dental wear is informative about the organization of labor there is a need to take into account both patterns of activity and occlusion.

Dental wear and age-grading at Roonka, Southeastern Australia

A major issue in dental anthropological analysis is the identification of intra-sample variation. For example, while analyses of dental wear among hunter-gatherers often give a seemingly uniform picture of heavy and rapid dental wear with loading on the anterior teeth (e.g. Begg, 1954; Deter, 2009; Hinton, 1981; Molnar, 1971a; Smith, 1984), there may be multiple patterns of wear amongst individuals creating this modal pattern (McKee and Molnar, 1988). Such variation may reflect individual idiosyncrasies due to unusual patterns of occlusion or particular dietary or work practices (Stojanowski et al., 2016). On the other hand, this variation may be patterned in ways that reflect social structures and practices. Many studies have focused upon behavioral variability between the sexes (Berbesque et al., 2012; Larsen, 1985; Merbs, 1983; Schulz, 1977). For example, recent analysis of tooth wear among Aboriginal groups on the Murray River, Australia, revealed much greater constraint in the variability of anterior wear among females from Euston. Dental wear patterns suggest that while male activities were varied, female activities were not, possibly reflecting a shared emphasis on the processing of particular foods (e.g. bulrush) as part of women's work (Littleton et al., 2013). Assessing age-related differences is more complicated since basic occlusal relationships change as wear progresses through adulthood. However, some studies have shown the acquisition of activities in early adolescence (Turner and Machado, 1983) or the possibility of increasing skill with age (Molnar, 2008). In many hunter-gatherer societies age brings with it changing roles and responsibilities and serves as an important organizing principle. For this reason, obtaining evidence on the nature and timing of age changes potentially illuminates a basic feature of social and economic organization. In this paper, I analyze the pattern of dental wear at Roonka on the lower Murray River, Australia. The question being evaluated is whether the pattern of wear by sex and by age reveals the probability of age-graded acquisition of tasks as well as basic functional relationships as wear progresses through adulthood.

PATTERNS OF DENTAL WEAR.

Examining the pattern of dental wear requires examining wear across the mouth of an individual rather than on individual teeth. Early work focused on the progression of wear in different populations (Murphy, 1959; Miles, 1963, 2001) generally with the aim of characterizing age related loss of enamel. Smith (1984), on the other hand, started to examine the transfer of wear across teeth characterizing the differences in occlusal loading between hunter-gatherers and agriculturalists as well as the development of a helicoidal plane (Smith, 1986). Gradients of wear relative to the first molar have more recently been studied in order to examine not just molar wear (e.g. Watson et al., 2013) but also patterns of usage of the anterior teeth and premolars (Clement et al., 2009; Clement and Hillson, 2012; Deter, 2009; Littleton et al., 2013). Wear on the anterior dentition can reflect non-alimentary use of the teeth and provides, therefore, a useful insight into the patterning of activity between and within groups. In addition, if it is assumed that if wear progresses on individual teeth at a regular rate then it is possible to compare groups for whom sample sizes are too small to consider ages separately or where age was not assessed (Clement et al., 2009; Littleton et al, 2013).

However, wear can reach a maxima where the worn tooth has no remaining enamel and the tooth roots are functional. Alternatively, the tooth may have been shed antemortem. In these cases wear may be transferred to neighboring teeth creating a flatter plane of wear as the other teeth take over functions previously borne by teeth that were later lost, or where use of the teeth as a tool is altered in an effort to accommodate having fewer teeth (Richards and Brown, 1981; Taylor, 1984). These functional differences can be expected in groups where older adults have experienced complete loss of enamel on some teeth.

The other possibility is that patterns of tooth wear change as individuals within a sample take on new activities or change diet. Such practices include the adoption of particular skills (e.g. stone tool manufacture) or particular tasks such as preparing hide (Molnar, 1972). Similarly, dietary changes reflected in the degree of abrasiveness may occur as children shift from being provisioned to provisioning for themselves or as food restrictions are lifted or put in place. Therefore, analyzing intra-sample patterns of wear by age and sex provides a method of examining past social and economic roles or patterns of life history. Nevertheless, this needs to be undertaken with ongoing consideration of differences that may be purely due to differences in the timing of dental eruption (Deter, 2009) or occlusion with age.

Many studies of dental wear among Australian Aboriginal people have detected differences between the sexes which are attributed commonly to differences in dietary abrasiveness (Campbell, 1939; Campbell and Barrett, 1953; Molnar et al. 1989; Richards and Brown, 1981). However, studies of age have focused more often upon the progression of wear (Murphy, 1959; Richards and Brown 1981) as opposed to whether differences between age groups reflect differences in diet and activity as well as functional relationships.

Yet Aboriginal societies are age graded. Changes in roles and responsibilities with age are marked by initiation ceremonies. Food taboos are often attributed to different ages and gender. Older men occupy roles of authority and influence (Berndt and Berndt, 1988; Eyre, 1845). Apart from these formal markings of age and role, there are changes that occur during the life-course. As children transition into adulthood they are treated differently and given different responsibilities that may impact on patterns of dental wear (Hamilton, 1981). But are these changes visible in the pattern of macrowear? Does the pattern of wear indicate the nature of these changes and does it suggest particular points of transition? Analyzing dental wear at Roonka, a site in southeastern Australia, provides an opportunity to address these questions.

ROONKA

Roonka is an Aboriginal burial ground located on the west bank of the Murray River, southeastern Australia (Fig. 1). Comprising at least 216 individuals, Roonka is the largest of only very small number of excavated Aboriginal burial sites. These individuals were buried primarily, although not exclusively, in a dune between the east side of an ancient lagoon and the main river channel. The site was excavated by Graeme Pretty from the South Australian Museum and a group of volunteers from 1968 to the mid-1970s (Walshe, 2009). It is an unusually complete excavation noteworthy for both its size and level of associated documentation.

[INSERT FIGURE 1 HERE]

The burials are assumed to be primarily Holocene in age although relatively few have been dated and the original dates have very large error margins. Recent redating of ten individuals yielded a range of ages from 4000 BP to the post-contact period (i.e. after 1840). While Pretty attempted a chronological analysis of the site, assuming that differences in burial style were associated with different dates, this association has not been confirmed by the recent redating with the possible exception of 'vertical' burials which may represent an early period of site use (Littleton et al., in press). In addition, burial style could not be reliably determined for many graves. The 'oldest' dated burial on the site is placed at c6000 BP but the recent redating was unsuccessful for this individual. The redating also produced a non-continuous distribution so it is not clear if use of the site was episodic or continuous. These limitations in dating mean that the site is time-averaged. While Smith et al. (1988) argue, based on non-metric dental traits, that there is no evidence of microevolutionary change at the site over time, the sample ought to be regarded as representing people buried at a single place, but not necessarily as representative of a single population.

Analysis of the archaeological finds at Roonka and nearby McBean's Pound suggest that people were using a mixture of terrestrial and riverine resources (Paton, 1983; Pretty, 1977). This is also supported by ethnohistoric descriptions of people living in this general area (Eyre, 1845). There is, however, debate about whether the site reflects intensive use of riverine and other local resources by a semi-sedentary population (Pate, 2006) or whether mobility varied in relation to environmental change. Given the lack of dating these arguments are hard to evaluate, but while acknowledging the time averaged nature of the site and its human remains it is possible to assess intra-sample variability. This has the potential to determine whether there is a consistent overall pattern of wear and age suggestive of continuity over time or internal variability suggestive of changes in human diet and activity patterns.

This paper therefore addresses wear in two stages: first, an assessment of the overall degree of wear, and second an assessment of the overall pattern of wear. The goals of these steps are to assess intra-sample variability and evaluate whether there are discrete groupings associated with particular wear patterns that might reflect change over time, or whether such groupings reflect consistent structuring of wear and wear patterns by age and sex reflecting diet and activity within the burying group(s).

MATERIALS

All human remains from Roonka were inventoried and are included in this analysis if they had a permanent tooth. Sex was assessed on the basis of standard pelvic indicators (Buikstra and Ubelaker, 1994). If the pelvis was not available the cranium was used taking into account the robusticity of Aboriginal remains (Brown, 1981). Age was determined using multiple indicators: pubic symphyseal aging (Brooks and Suchey, 1990), sacro-auricular aging (Lovejoy et al., 1985), and cranial suture fusion (Meindl and Lovejoy, 1985) where possible, while for younger individuals, closure of the epiphyseal surfaces (Buikstra and Ubelaker, 1994) and dental eruption and formation were also used. The timing of eruption of the second molar and third molar were assumed to be c12 years and 16 years, respectively, based on the work by Brown (1978) on Aboriginal children from Yuendummu. The final age classes were child (<11 years), juvenile (12-16 years), young adult (17 – 35 yrs), middle adult (36- 50 years), old adult (50+ years).

Of the 216+ individuals excavated or collected from Roonka, 126 have at least one permanent tooth or socket. The age and sex distribution of these individuals is given in Table 1. There is no statistically significant difference in the numbers of males and females represented in the sample overall, but there are more females than males among the young adults, while individuals of indeterminate sex comprise most of the juvenile sample or the group where age could not be assessed beyond 'adult'. These imbalances are considered when interpreting any comparisons across sex and age.

[INSERT TABLE 1 HERE]

METHODS

Wear was scored using the Scott system (1979) across the entire dentition (Littleton and Frohlich, 1993). Since each cusp is scored separately on a 0-10 scale, the resultant maximum scores are 40 for the molars, 20 for the premolars and 10 for the incisors and canines. All cuspal scores for a single tooth were averaged to provide a final 10-point score.

In order to test for intra-observer error, 30 individuals with complete dentitions were rescored two weeks after the initial recording. These replicate scores for each tooth were assessed using intra-class correlations for degree of absolute agreement (Table 2).

INSERT TABLE 2 HERE]

Correlations were 0.949 and over indicating excellent agreement between the two sets of scores. During initial recording, however, we noted that the better results were obtained if we read the scoring diagram as a series of thresholds (i.e. the diagram shows the *entry* point into a score category rather than an undefined average).

The pattern of wear was analyzed by calculating the gradients of wear of each tooth relative to the M1 of the same arch (x tooth wear/M1 wear score * 100). While interval scale data would be desirable for statistical purposes, ordinal data are most appropriately compared using non-parametric statistics. In addition, the Scott system of recording captures teeth at low degrees of wear not captured if only dentine exposure is used. Statistical analysis for asymmetry between wear on the antimeres demonstrated no significant differences with the exception of the lower third molars (Wilcoxon Signed Rank test statistic = 2.377, $p = 0.017$) where differences are due to both agenesis of opposing third molars and unequal occlusion. Consequently, the most complete upper and lower quadrant was used for each individual but with caution around the third molar gradients.

IBM SPSS v21 statistics software was used for statistical analyses. Degree of wear was compared using Mann-Whitney U tests for two independent samples and the Kruskal-Wallis H test for more than two samples. Alpha levels were adjusted for multiple comparisons using the Bonferroni correction. Parametric values are also shown in accompanying tables since data using multiple ranks can be argued to be amenable to such tests (Conover and Iman, 1981, Rose and Ungar 1988). The pattern of wear was analyzed visually through the use of box-plots showing interquartile ranges and tested statistically by comparing the M2/M1, P3/M1 and I1/M1 gradients. All gradients had a normal distribution (Shapiro-Wilks test $p > 0.05$ except for the maxillary P3/M1 gradient) hence comparisons were undertaken using ANOVA and the Kruskal-Wallis H test. This form of analysis treats the individual gradients separately. In order to test whether there are coherent patterns, cluster analysis was undertaken using both hierarchical cluster and K-means cluster methods based on the number of upper level divisions in the hierarchical analysis. Subsequent cluster membership was tested against age and sex (using Chi-square analysis) to assess whether particular patterns were found in specific groups.

RESULTS

Overall degree of wear

Dental wear proceeded rapidly among the Roonka individuals with marked wear on the incisors as well as the first molar. As shown in Figure 2, the overall distribution of dental wear at Roonka only loosely follows the pattern of wear expected from timing of dental eruption. Across the entire sample, the four incisors are worn almost as much as if not slightly more than the first molar despite erupting consistently later. Wear on the later erupting canine is near equivalent to the first molars despite at least four years' difference in average eruption time. While the order of wear on the premolars matches eruption timing (P3 worn more than P4), this is more marked in the maxilla than the mandible. Wear on P4 is roughly equivalent or slightly greater than the M2 and there is a regular decline in wear from the M1 to M3.

[INSERT FIGURE 2]

Wear in each tooth type increases significantly with age (Kruskal-Wallis H test, $p < 0.001$). Comparison of the degree of dental wear against age group shows a very strong positive correlation for the first and second molars and mandibular P4 (Table 3, Spearman's $R > 0.80$). All other teeth showed strong positive relationships with age (Spearman's R between 0.65 and 0.77, Fig. 3). The difference between the regular age-related progression of wear in the M1, M2 and mandibular P4 versus the other teeth, particularly anterior, suggests different factors affecting the anterior and central dentition than the posterior. This coincides with the observation that average wear scores most consistently align with eruption sequence for molars with greater than expected attrition particularly in anterior dentition.

INSERT TABLE 3

There is very little difference between the sexes in the degree of wear. Comparison across the entire sample by tooth type indicates no statistically significant differences when the alpha level is adjusted for multiple comparisons (alpha = 0.003). Undertaking that comparison for each tooth type and age group indicates that there was a tendency for anterior female teeth to be less worn than male teeth in the young adult age group, but the only statistically significant difference (adjusted alpha = 0.016) was for the degree of LC wear among Middle Adults (Mann-Whitney U=7.519, p = 0.016). In these analyses the results of the parametric results mirror those obtained with non-parametric, but such mirroring cannot be generalised to all such comparisons. The Roonka sample encompasses a wide range of ages and the full range of attrition grades thus maximising ranked data.

Pattern of wear

The gradients of wear were examined in order to identify variation in the rate of wear on the molars in particular and differences in the weighting of wear across the mouth (Table 4, Fig. 3). As suggested by examination of the average degree of wear, wear gradients relative to the first molar indicate heavy anterior wear for most individuals at Roonka on both the maxilla and mandible (Fig. 3). Wear on the maxillary premolars is also heavier than expected given eruption timing, although less than observed on the anterior teeth. The upper quartile of P4 exceed wear on their first molar, and 50% of the P3 are worn beyond their M1. In contrast, the mandibular premolars are relatively less worn. There is very little difference between the maxillary and mandibular molars. The range of wear on the M3 is very wide reflecting occlusion patterns and agenesis of opposing teeth. However, there is in general a regular progression of lesser wear from the M1 to M3. The ranges on all other teeth exceed the range on the M2 suggesting that the differences in gradients may be due less to the texture of food than to non-masticatory uses of the teeth.

[INSERT TABLE 4, FIGURE 3]

These sample averages may, however, disguise internal variation within the Roonka sample. Males and females follow the same general pattern of heavy anterior wear although, as shown in Fig. 4, females seem to have modestly more, and more variable, wear on their mandibular incisors than males (Fig. 4). There is no comparable difference in the anterior maxilla between the sexes. However, these differences in median, mean and dispersion are not statistically significant (Table 4). There are also no differences between males and females in the pattern of wear for either the molars or the premolars. Such results confirm the lack of sex differences seen in the degree of wear.

[INSERT FIGURE 4]

Patterns of wear do differ by age (Fig. 5). Although there are relatively few juveniles their anterior teeth were found to have larger coefficients of variation in wear (Table 4). Among the young adults, from less than 25% to about 50% have anterior tooth wear that does not exceed that of their M1s and there are two canine outliers with very little wear (Fig. 5). There are statistically significant differences in the I1/M1 gradient for the mandible between age groups and between and post hoc comparisons of the juvenile, middle and old adult maxillae (Table 4). The young adults do not show signs of heavier premolar wear except for a small number with heavier wear on the upper P3. The molar gradients are slightly steeper (i.e. lower) than for older adults. These differences are statistically significantly different for the mandible (juvenile vs young adult vs middle adult).

[INSERT FIG. 5]

Among the middle adults there is the same level of anterior wear but less variation with a large majority having more wear on the anterior teeth than the first molar (Fig. 5). The change is within the premolars particularly the mandibular P3/M1 gradient, which is statistically significantly different from that observed among the young adults (Table 4). The premolars are now worn more relative to the M1 and there is a decrease in the degree of variability in the maxillary P3/M1 gradients. Even so the premolars are not worn as severely as the anterior teeth. The shift to greater premolar wear corresponds to what is observed in the raw scores of wear.

There is a marked contrast with the old adults where the gradients have flattened out and first molar wear exceeds anterior and premolar wear (Fig. 5). Old adults are those who have survived middle adulthood so the decline could have three potential causes. One, it could be that those who survived to old adulthood didn't undertake the same work patterns as younger individuals throughout their life. Two, as crown height is lost and teeth become painful and occlusal relationships change, wear shifted may have shifted to neighboring teeth (Barrett, 1958; Taylor, 1984) creating a flatter plane. Three, that teeth were lost ante mortem leaving the less worn anterior teeth among old adults, however, this seems unlikely given the low rates of ante mortem tooth loss in the sample (1.9% of teeth, 13.9% of individuals but mostly with only one lost tooth).

These analyses have examined the pattern of differences between individual tooth gradients but do not consider the influence of all available teeth together in individuals' mouths. Cluster analysis was undertaken using a subset of individuals possessing a complete maxillary and mandibular arch (n = 37) to test whether the trends seen in these gradients with age corresponded to patterns of wear among individuals. Two methods were used: a hierarchical cluster was undertaken using the M2/M1, P3/M1 and I1/M1 gradients for both the mandible and maxilla. The resultant tree was examined to identify the number of major groupings. Three to four major branches were identified so K-means clustering was undertaken using four as the desired number of clusters. The results show a cluster of individuals with heavy wear on the anterior teeth but roughly equivalent wear on premolars and molars (cluster 1); another group with a steeper molar gradient, heavy anterior wear particularly on the maxilla and little wear on the premolars (cluster 2); a third group with a relatively flat plane of wear (cluster 3); and a fourth group with heavy anterior and premolar wear (cluster 4) (see Table 5).

[INSERT TABLE 5]

Cluster membership was then assigned to all possible individuals on the basis of the six gradients. Comparing the distribution of these four clusters within the age groupings reflects what was suggested by the boxplots: these different patterns occur more frequently in particular age groups (Fig. 6, Table 6). Cluster 2 is more common among the juveniles than expected by chance (Chi-squared, $p < 0.005$). Young adults generally showed the pattern of heavy anterior wear (cluster 1, $p < 0.005$) but, coinciding with the wide variability of this age group, a large number of young adults also show a flatter plane (possibly more equivalent to the pattern of eruption, cluster 3). Cluster 3 (the flatter plane of wear) is the predominant type of wear among the old adults while middle adults are classified frequently as Cluster 3 and Cluster 4 (heavy anterior and premolar wear). There is no significant difference between males and females in terms of cluster pattern, but individuals for whom sex could not be identified are predominantly classified as members of cluster 1 or 2, which presumably reflects the fact that most of the unsexed individuals are juveniles or young adults (Fig. 7). What the cluster analysis indicates is that the trends described above are indeed coherent but not discrete groups; that is, there is an age graded pattern, but in all groups there are some individuals with flatter wear or wear more concordant with the pattern of eruption (i.e. Cluster 3).

[INSERT TABLE 6, FIGURES 6 and 7]

DISCUSSION

The pattern of heavy anterior wear relative to molar wear is a common, but not universal, finding among hunter-gatherer populations (Begg, 1954; Clement and Hillson, 2012; Deter, 2009; Molnar, 1971a; Richards and Brown, 1981; Smith, 1984). As Deter (2009) demonstrates in her study of hunter-gatherer and agricultural populations, despite this heavier loading among foragers, in both groups the degree of wear reflects the order of tooth eruption. In her study populations, the central incisor and first molar are the most worn teeth at all ages. What is observed at Roonka is that commonly the degree of wear on the anterior teeth and premolars does not follow the pattern of eruption although generally wear on the molars does follow eruption. Furthermore, comparison by age also shows that by old age patterns of wear are changing, becoming flatter in a way that is consonant with Barrett's (1958) observations of Aboriginal people at Yuendummu or Moody's (1949) observations in the Northern Territory. Clearly the pattern of wear results from this combination of the way in which teeth are used, the order of the eruption, and the changed occlusal relationships resulting from age (and dental wear itself).

The overall degree and pattern of macrowear at Roonka is similar to that observed at Gillman on the Adelaide Plains (Fig. 8) and by extension the neighboring region of the Murray River (Middle A as per Fig. 1, Littleton et al., 2013). It corresponds to a group where most individuals probably used their anterior teeth in non-masticatory ways. Premolars were similarly used, albeit to a lesser degree. The second molars in all these three groups have relatively little variability suggesting a lack of difference in dietary abrasiveness. This pattern contrasts to the Yorke Peninsula sample where wear largely follows the pattern of dental eruption or Euston further upriver where it is suspected that many members of the group are heavily involved in the processing of typha. In all of these comparative groups, however, wear is gendered not just in pattern but also in terms of the degree of variability between males and females. In contrast, Roonka does not show any clear divisions between males and females. This is not proof that such divisions did not exist; the Roonka sample covers a long time frame so any shifts in the pattern of activity by sex (as observed elsewhere) may be averaged out in the sample. Secondly, there is the issue of equifinality, different tasks resulting in the same macrowear pattern. This possibility can be tested through examination of microwear patterns in the future.

[INSERT FIGURE 8]

In all individuals age is associated with differential wear on the tooth row because of the pattern of eruption (Deter, 2009). Brown's (1978) studies of Aboriginal people at Yuendumm reveal the teeth erupt in three groupings: M1, I1, I2 first; followed by [C, P3], [P4, M2] (brackets indicate where the order may be reversed); and finally the M3 (Brown, 1978). At Roonka this pattern of the earlier erupting teeth being most worn corresponds most closely to the pattern observed among members of Cluster 3, which is observed in all groups, but most frequently among older adults. However, in older adults where there is significantly less difference between wear on the M2 relative to the M1, the flatter pattern seems to be the result of loss of crown height and the transferral of loading across the teeth. Younger individuals in cluster 3 (22.2% of juveniles and 35.7% of young adults) do not have the disproportionate heavy anterior wear observed in clusters 1 and 2 (66.7% of juveniles, 42.9% of young adults).

This distribution of cluster membership with the high degree of variability in heavy anterior wear in this age group suggests heterogeneity in factors creating attrition. These include diet, occlusion, as well as non-masticatory use of teeth (Molnar, 1971b; 1972). The patterning of anterior wear suggests that the use of the incisors and canines as a third hand is established during the juvenility and young adulthood as younger members start to take up manufacturing or food processing tasks on a regular basis. However, there is no clear indication of a precise age when this occurs; after all, some individuals avoid this anterior wear completely and there is no apparent sign that initiation of anterior tooth use varies by sex of younger individuals.

Ethnographic records from the region emphasize the distinction between younger children and juveniles and then between juveniles and young adults. The most complete record of observations come from Eyre who lived at Morrunde (c10 km downstream from Roonka) from 1841-1845. He recounted that at about nine to ten years of age children began foraging for themselves (Eyre, 1845: 151) rather than being provisioned by adults – a point at which the abrasiveness of food might be expected to change. This is not visible in the macrowear since their dentition remains mixed with two deciduous molars and one M1.

At about 14 to 16 years of age both boys and girls underwent initiation ceremonies and further food taboos are introduced. Eyre, however, does not specifically mention the uptake of different activities and tasks but points out that while children enjoyed "learning the occupations and pursuits of after life, as to make twine, and weapons; to ascend trees; to procure food; to guide the canoe, and many other things…. The elder boys engage more extensively in similar occupations, as they are more particularly interested in them, and by their exertions have to provide chiefly for their own support (Eyre, 1845: 83)." After initiation, the young men often camped together in bachelor's camps. Curr, describing a camp further upriver, says that the older bachelors cooked for themselves although the quite young ones were provided for by the family (Curr, 1883: 256). Indications of Aboriginal people visiting Adelaide suggests men were more mobile than the whole family and that they were still subject to food taboos (Eyre, 1845: 150, 231). This ethnographic evidence indicates that there may be differences in food and activity patterns among males as suggested by the macrowear patterns. Females, however, were married around 16 years of age and therefore resided within a productive family unit where it might be expected that they would be taking up tasks different from those of males, yet there are no indications of significant sex differences in the pattern of wear at this age. The wide variability seems to reflect both the variability in living circumstances and probably the acquisition of skills among young people.

There is less variability among middle adults. The majority not only have heavy anterior wear but also significant wear on the premolars, particularly P3. A pattern of non-occluding premolar wear in some individuals (Fig. 9) suggests the stripping of material as it is pulled across the premolar and either up or down on the buccal surface. According to ethnographic descriptions from Moorunde and elsewhere in Southern Australia, both females and males were engaged in the labor of producing nets and other fiberwork, preparing fiber by either carding it with the hands and teeth or chewing it (Eyre, 1845: 167). A similar pattern has been observed among some ancient central Californians (Griffin, 2014: Fig. 10).

[INSERT FIGURE 9]

Presumably there is a range of activities that can produce heavier premolar wear but at Roonka this is the middle adult age group where the pattern of wear is more uniform. It corresponds to demographic expectations that at middle age adults are providing for young children and have greater responsibilities. Males, according to Eyre (1845), marry around 25 years of age and resided as members of family groups so presumably there are a range of influences that could make for less inter-individual variability: greater shared resources (such as nets) and hence responsibility for their production, potentially reduced mobility compared to some of the young men, and fewer food taboos. It is probable that this more uniform pattern of macrowear continued into old adulthood, but is transferred to a flatter plane as the teeth lose crown height.

Differences in responsibilities and tasks with age are commonly observed in hunter-gatherer societies. At Roonka the dental wear suggests there was a degree of leeway in the activities of young adults and presumably variability in skill acquisition as well. However, among middle adults it appears most had responsibility for shared patterns of activity. The range of activities and whether they are sex-specific can be addressed in future research by examining the pattern of microwear to see if there are dominant patterns of scratch size and direction.

Age is a significant organizing principle in Aboriginal societies. The respect given to older men and their capacity to marshal the reproductive labor of younger women is well recognized (Eyre, 1845; Keen, 2004). Similarly, the importance of initiation (at Roonka marked by avulsion of incisors for some individuals and tattooing) points to the significance of the transition from juvenile to adult for males (Durband et al., 2014; Eyre, 1845) while changed food taboos are associated with the female transition to adulthood (Berndt et al., 1993). The dental wear suggests that age is more than just a matter of ceremony and ritual practice but permeates the activity patterns of the group. There does not seem to be a set age at which activities involving the anterior teeth as tools are taken up, for even young juveniles appear to have participated in such work. But clearly by middle adulthood both males and females have settled down to what appears to be shared work and very few individuals appear to have avoided these activities. This may continue among old adults but the pattern of wear at this age is complicated by changes in occlusion pointing to how analysis of wear needs to take into account the fundamental changes occurring with advancing age.

These trends are coherent but should be recognised as trends, not as discrete groups. This is for two reasons. First, the overlap in the patterns of wear between ages may be indicative of the effect of time-averaging, i.e. at some points in time work and food patterns were more constrained to different ages than at others. Alternatively, it may be that there was always some level of variation between the practices of individuals. This question cannot be solved without further dating. However, the strong trends by age compared to the wide variability seen in other samples (e.g. Yorke Peninsula, Littleton et al., 2013) suggest a degree of temporal consistency. Similarly, the lack of difference between the sexes may indeed be reflective of practices at Roonka and in contrast to groups both down and upriver. However, work on the Adelaide Plains suggests that sex differences in the pattern of wear may reverse over time – reducing any indication of variability (Littleton et al., 2013). In addition, macrowear itself is a cumulative process, the result of multiple forces impacting over the individual's lifetime, so the possibility is that males and females are eating foods of similar abrasiveness and undertaking separate tasks that result in a similar macrowear pattern. This can be tested further by microwear analysis.

CONCLUSION

Modal patterns of macrowear within a sample are meaningful. In this instance Roonka shows a pattern of wear that is consistent with its regional position. Yet further analysis demonstrates how this regional pattern is created out of internal patterns of age and sex that are not monolithic but act as central tendencies. Certainly, they affirm that age is an important organizing principle but they also show a range of variability that might be the result of the range of hunter-gatherer activities or, in archaeological contexts, time-averaged shifts in behavior over time. They do not point to the concentrated lack of variability seen among individuals recovered from the area of Euston or, as far as we can see, the wide range of variability observed in the space and time averaged sample from Yorke Peninsula (Littleton et al., 2013). The analysis does serve as a reminder that while wear is often thought to progress straightforwardly with age this is not a necessarily linear relationship because of both functional effects, such as changing occlusion, and differences involving the nature of a life course within and across different societies.

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TABLE 1: Age and sex distribution of individuals with at least one permanent tooth or one permanent socket and of the total number of teeth.

Age Group	Female (%)	Indeterminate (%)	Male (%)	N
N. of individuals				
Child	0	100	0	11
Juvenile	0	75.00	25.00	12
Young adult	52.80	8.30	38.90	36
Middle adult	46.70	0.00	53.30	30
Old adult	47.40	10.50	42.10	19
Adult (age unknown)	5.60	77.80	16.70	18
Total	34.10	31.00	34.90	126
N. of teeth and/or sockets				
Child	0.00	100.00	0.00	90
Juvenile	0.00	80.50	19.50	236
Young adult	51.10	6.40	42.50	771
Middle adult	43.90	0.00	56.10	748
Old adult	44.40	9.50	46.00	430
Adult (age unknown)	13.80	54.40	31.80	195
Total	38.10	19.30	42.70	2470

Table 2: Analysis of average intra-class correlations testing for intra-observer error.

Tooth type	Correlation	CI	F	P	N
Molars	0.979	0.972-0.985	47.969	.008	180
Premolars	0.965	0.952-0.976	29.121	<0.0005	133
Anterior teeth	0.949	0.925-0.964	20.872	<0.0005	152

Table 3: Nonparametric correlation coefficients for degree of wear against age group.

Tooth	Spearman's R	P	N
UM3	0.687	<0.0005	105
UM2	0.821	<0.0005	134
UM1	0.817	<0.0005	147
UP4	0.762	<0.0005	136
UP3	0.718	<0.0005	130
UC	0.696	<0.0005	125
UI2	0.684	<0.0005	111
UI1	0.668	<0.0005	98
LM3	0.710	<0.0005	124
LM2	0.850	<0.0005	137
LM1	0.833	<0.0005	144
LP4	0.814	<0.0005	138
LP3	0.773	<0.0005	129
LC	0.674	<0.0005	130
LI2	0.712	<0.0005	119
LI1	0.729	<0.0005	113

Table 4: Descriptive statistics for molar, central and anterior gradients by age and sex. Figures in bold identify statistically significant differences using a Bonferroni correction in order to adjust alpha levels for multiple comparisons.

	Maxilla					**Mandible**				
	Median*	**Mean****	**SD**	**N**	**CV**	**Median***	**Mean****	**SD**	**N**	**CV**
M2/M1 (Molar)										
Children	58.93	58.93	17.68	2	0.30	44.44	42.75	15.31	3	0.36
Juveniles	62.60	**65.15**	12.59	8	0.19	**62.50**	**60.92**	8.67	9	0.14
Young adults	76.19	72.71	13.74	23	0.19	**75.04**	**73.89**	8.06	25	0.11
Middle adults	80.00	76.51	10.83	25	0.14	**87.31**	**87.42**	9.73	22	0.11
Old adults	85.54	**81.63**	11.68	13	0.14	**95.83**	**89.90**	14.35	12	0.16
Total	76.67	74.30	12.96	77	0.17	79.30	77.80	15.67	75	0.21
Females	76.19	74.08	10.92	31	0.15	79.30	80.59	12.54	27	0.16
Males	81.81	77.43	13.58	33	0.18	85.05	81.84	14.41	34	0.18
P3/M1 (Centro-posterior)										
Children	-	47.62	.	1		55.55	46.77	16.61	3	0.36
Juveniles	80.00	88.29	24.65	9	0.28	**63.96**	**66.96**	16.56	8	0.25
Young adults	97.37	97.86	15.80	23	0.16	**75.44**	**76.87**	10.97	23	0.14
Middle adults	101.14	103.32	12.45	24	0.12	**88.89**	**90.31**	17.93	23	0.20
Old adults	98.17	94.57	27.06	13	0.29	**82.03**	84.15	13.06	10	0.16
Total	98.15	97.90	19.70	75	0.20	79.96	79.96	17.86	71	0.22
Females	100.28	101.28	14.27	30	0.14	87.17	87.88	17.99	23	0.21
Males	100.00	101.90	20.43	33	0.20	81.15	81.25	13.61	33	0.17

Table 4 cont.: Descriptive statistics for molar, central and anterior gradients by age and sex. Figures in bold identify statistically significant differences between age or sex groupings using a Bonferroni correction in order to adjust alpha levels for multiple comparisons.

I1/M1 (Antero-Posterior)										
Children	129.76	134.88	57.82	4	0.43	139.05	138.57	4.00	4	0.03
Juveniles	144.76	**135.14**	21.22	6	0.16	**112.50**	111.94	23.73	7	0.21
Young adults	116.00	117.36	15.28	16	0.13	**114.55**	112.96	19.50	23	0.17
Middle adults	115.34	**111.80**	16.87	20	0.15	**111.17**	110.08	17.80	16	0.16
Old adults	107.18	**106.31**	23.09	6	0.22	**88.89**	90.63	15.12	7	0.17
Total	115.34	117.60	22.80	56	0.19	**112.00**	111.1	13.20	61	0.12
Females	114.36	110.87	16.56	22	0.15	**120.50**	112.67	22.86	21	0.20
Males	116.25	116.64	17.96	21	0.15	**100.00**	104.02	15.32	26	0.15

* Tested using Kruskal-Wallis H test for independent samples, alpha level adjusted using Bonferroni correction factor. Figures in bold indicate statistically significant results.

** Tested using ANOVA, figures in bold indicate statistically significant results using post hoc comparison with a Bonferroni correction.

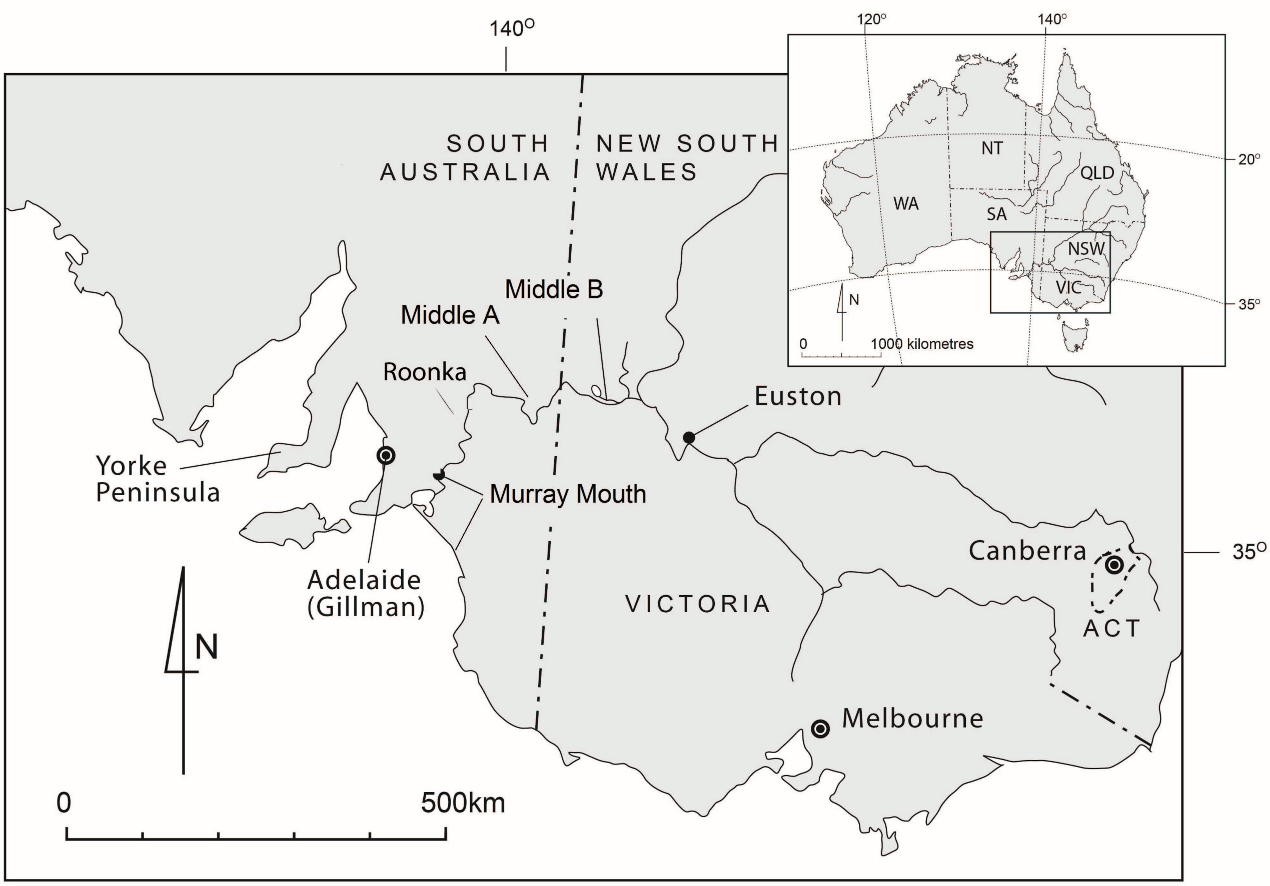
Table 5: Final cluster ~~centres~~ centroids for the gradients based on K-means cluster analysis and using the 37 individuals with a complete maxillary and mandibular arch.

	Cluster			
	1	2	3	4
M2/M1max	76.76	52.85	75.87	73.10
M2/M1mand	73.89	59.86	82.97	80.45
P3/M1max	85.73	80.67	97.75	112.81
P3/M1mand	73.55	53.46	78.33	100.75
I1/M1mand	129.08	97.49	92.16	122.52
I1/M1max	121.68	132.17	104.45	126.13
N. in cluster	9	3	14	11

Table 6: The distribution of cluster membership by age. Figures in bold identify the statistically significant deviations from expected values ($p<0.0005$).

Cluster	Juveniles		Young adults		Middle adults		Old adults		
	N	$(O_i-E_i)/\sqrt{E_i}$	N	$(O_i-E_i)/\sqrt{E_i}$	N	$(O_i-E_i)/\sqrt{E_i}$	N	$(O_i-E_i)/\sqrt{E_i}$	N
1	5	0.665	11	**2.170**	3	-1.157	0	**-1.928**	19
2	7	**2.794**	1	-1.486	1	-1.486	4	0.913	13
3	4	-1.204	10	-0.376	13	0.518	10	1.026	37
4	2	-1.179	6	-0.378	11	1.512	4	-0.236	23
N	18		28		28		18		92

Chi-square = 30.05, df = 9, $P < 0.0005$


140°
SOUTH AUSTRALIA
NEW SOUTH WALES
Middle B
Middle A
Roonka
Euston
Yorke Peninsula
Murray Mouth
Adelaide (Gillman)
VICTORIA
Canberra
ACT
35°
N
Melbourne
0
500km
120°
140°
NT
QLD
WA
SA
NSW
VIC
20°
35°
1000 kilometres

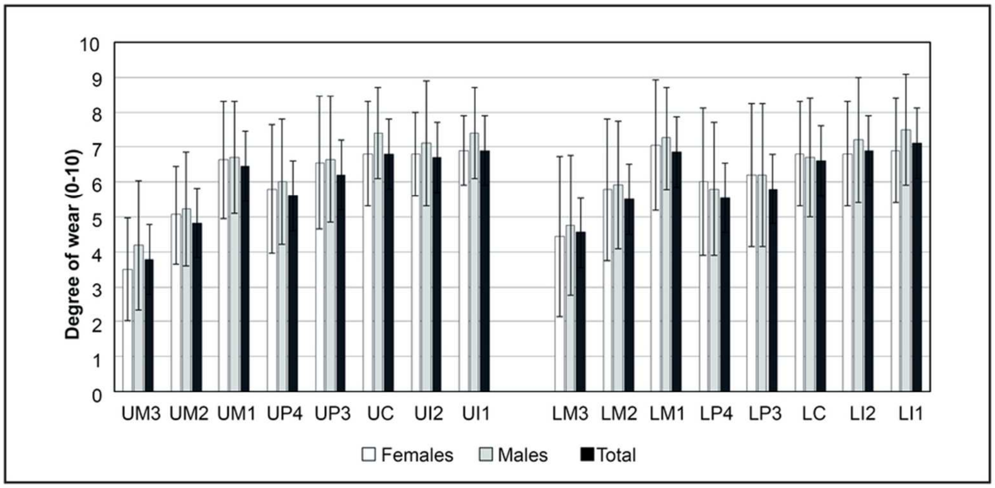


Figure 2: Average degree of wear by tooth type for males, females and the entire sample (12 yrs +).
Figure 2
82x40mm (300 x 300 DPI)

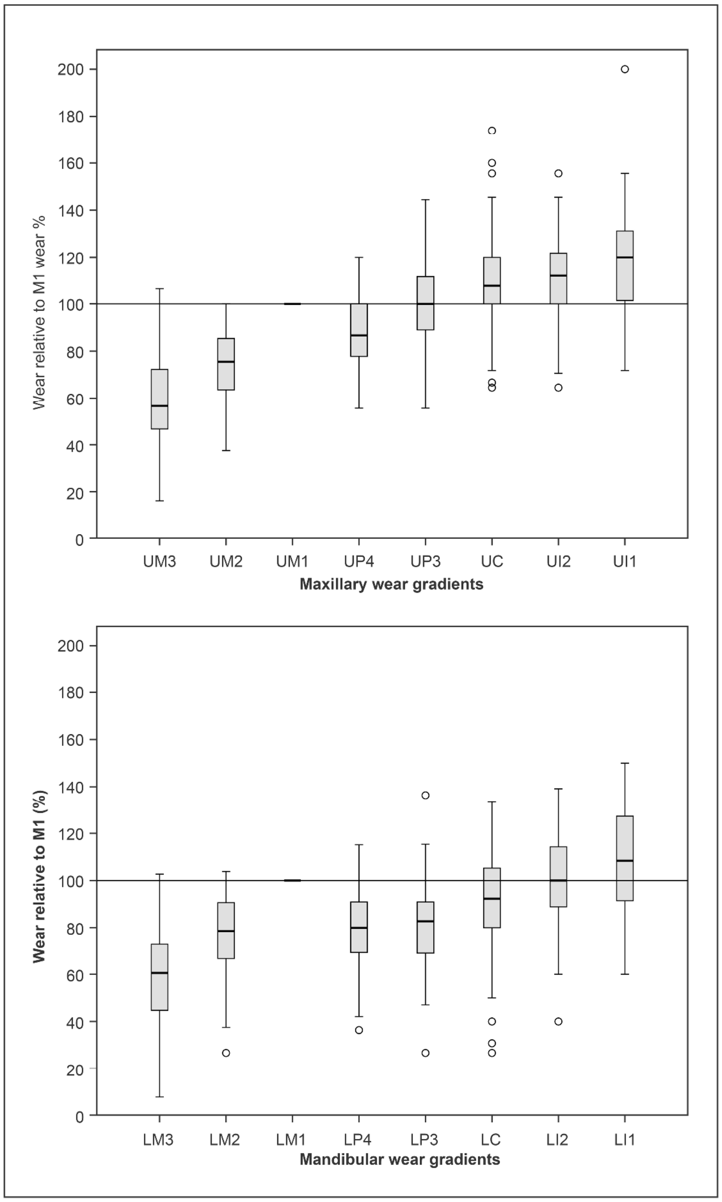


Figure 3: Boxplot showing interquartile ranges and outliers for maxillary (upper graph) and mandibular gradients of wear for each tooth relative to the M1. (For each age group the order of teeth runs from M3 on the left to I1 on the right.)
Figure 3
292x484mm (300 x 300 DPI)

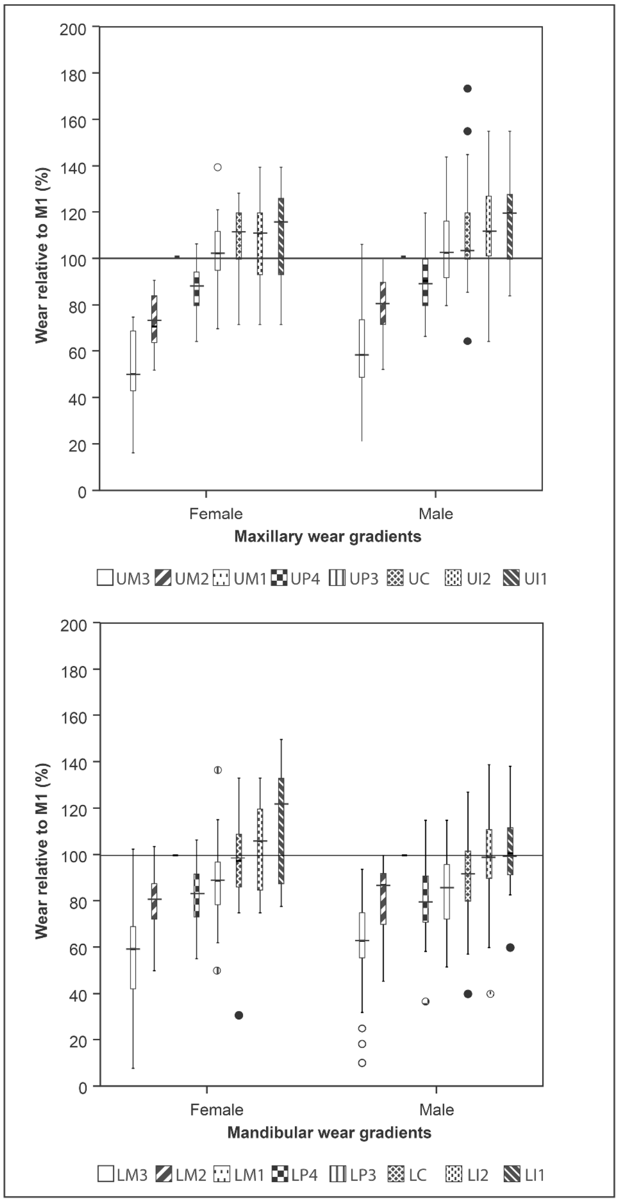


Figure 4: Boxplot showing for males and females the interquartile ranges and outliers maxillary (upper graph) and mandibular gradients of wear for each tooth relative to the M1. (For each age group the order of teeth runs from M3 on the left to I1 on the right.)
Figure 4
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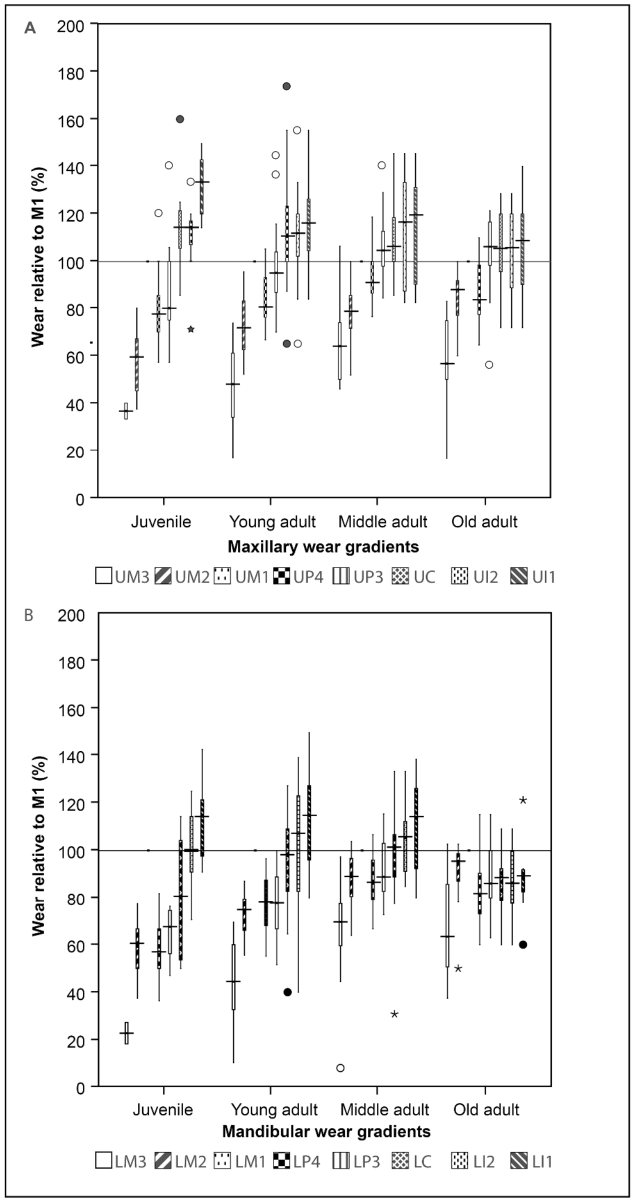

Figure 5: Boxplot showing for each age group the interquartile ranges and outliers for maxillary (upper graph) and mandibular gradients of wear for each tooth relative to the M1. (For each age group the order of teeth runs from M3 on the left to I1 on the right.)
Figure 5
281x533mm (300 x 300 DPI)

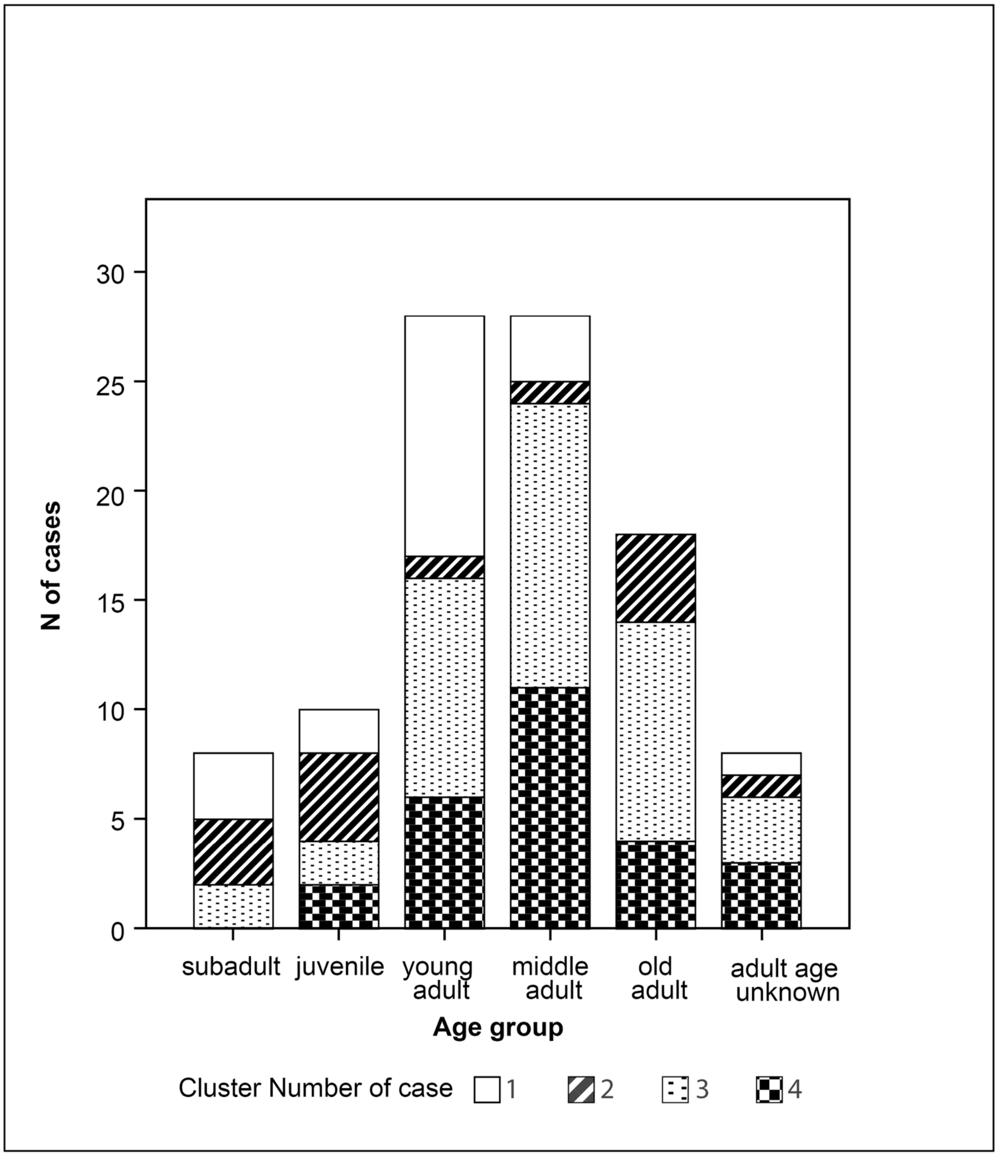

Figure 6: The distribution by age group of cluster membership.
Figure 6
171x198mm (300 x 300 DPI)

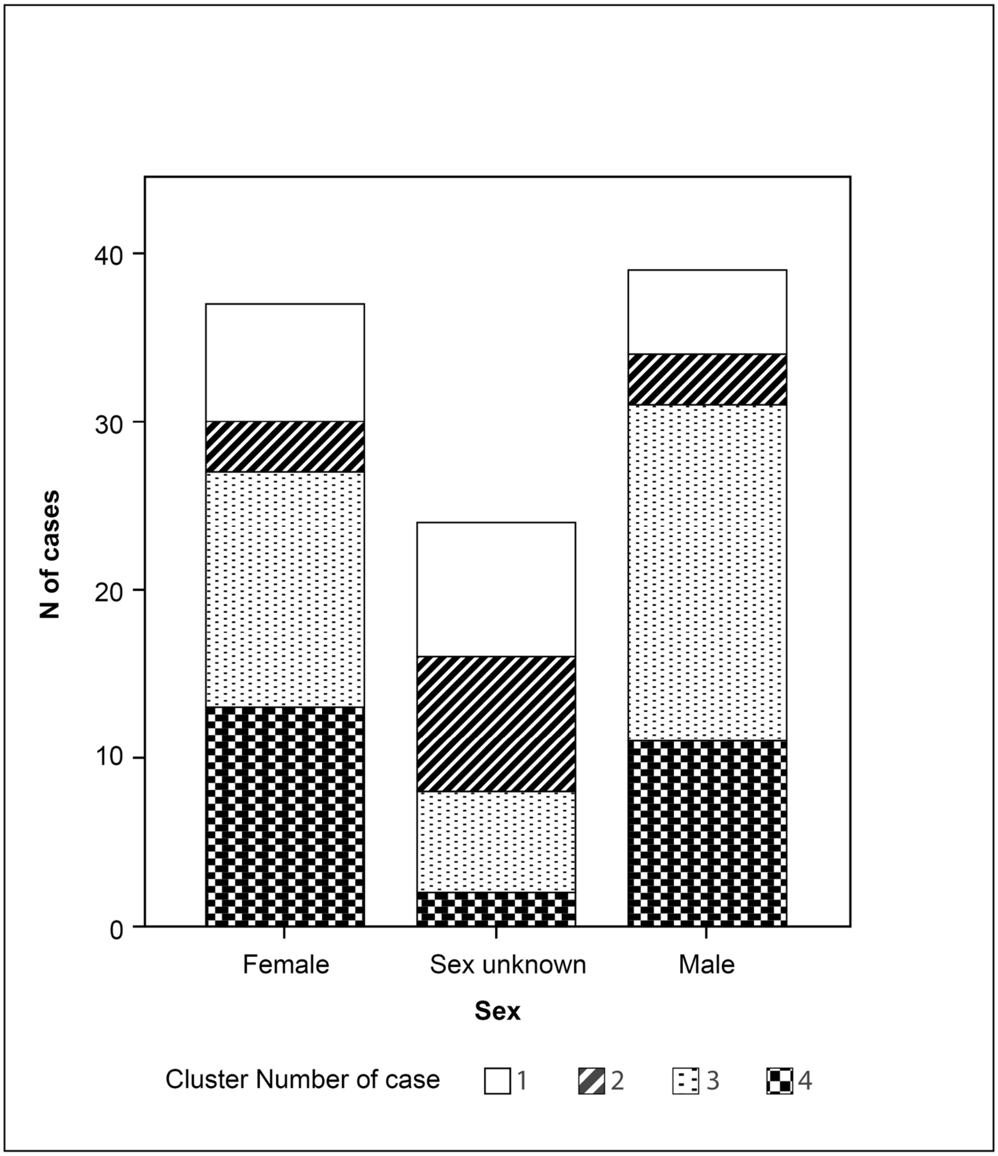

Figure 7: The distribution by sex of cluster membership.
Figure 7
171x198mm (300 x 300 DPI)

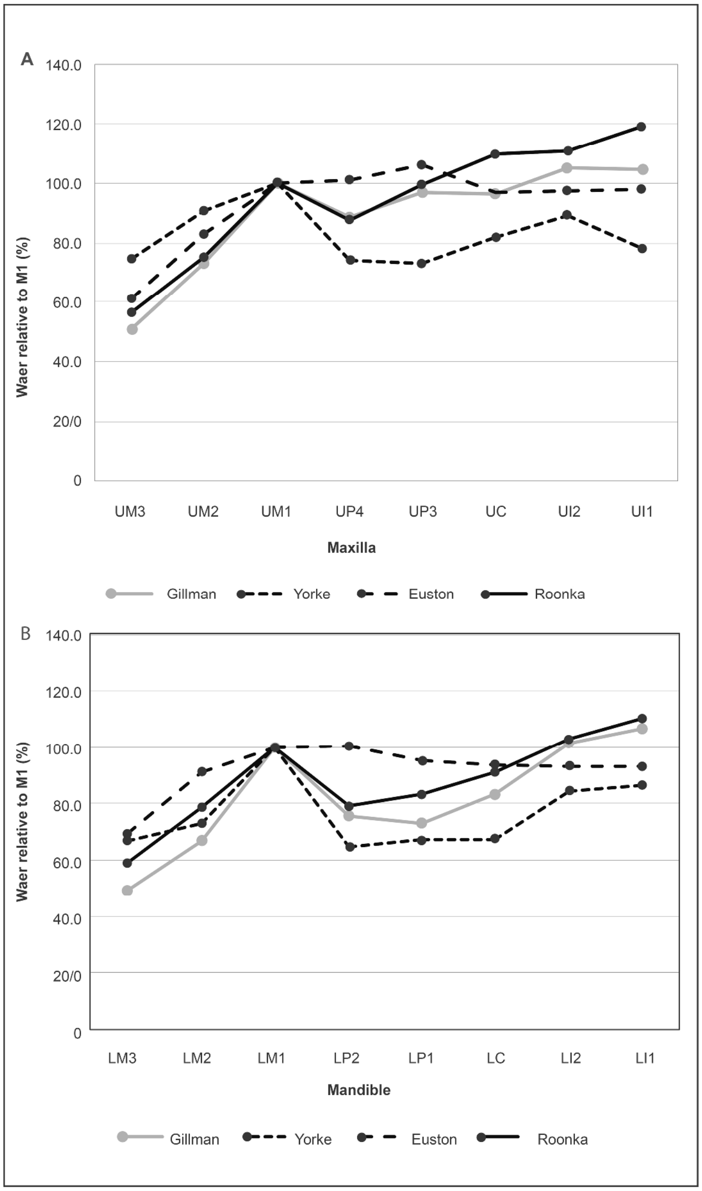

Figure 8: The pattern of wear at Roonka compared with other southern Australian samples (Gillman, Euston and Yorke peninsula, Littleton et al. 2013).
Figure 8
258x434mm (300 x 300 DPI)

Figure 9: Non-occluding premolar wear on an adult from Roonka (cluster membership = 4).
Figure 9
209x157mm (300 x 300 DPI)