Carter, F and Irish, JD

A sub-continent of caries: prevalence and severity in early Holocene through recent Africans

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Here we assess how dental caries frequencies differ by time period, sex, environment, and subsistence strategy among a range of populations across sub-Saharan Africa. Severity is also briefly discussed. Carbohydrate intake, adoption of agriculture, and behavioral and biological differences between the sexes and among populations all influence dental decay, so the latter can be highly informative (Turner, 1979; Newbrun, 1982; Larsen, 1997; Lukacs and Largaespada, 2006; Lukacs and Thompson, 2008). Yet relatively few dental pathology studies have been conducted within this vast region (Irish, 1993). Those that have, focus largely on qualitative data or are small in spatiotemporal scope (Flower, 1889; Shaw, 1931; Frencken et al., 1986; Morris et al., 1987; Solanki et al., 1991; Sealy et al., 1992; MacKeown et al., 1995; Steyn et al., 1998; Cleaton-Jones et al., 2000; Ohinata and Steyn, 2001; Pistorius et al., 2002; Steyn, 2003). The present study is much more comprehensive, covering the sub-continent from 10,000 years ago to present. At this large scale, the trends observed can work to support and/or refute those observed elsewhere in the world. The findings are discussed in terms of diet and other biocultural practices known to affect dental health.

The present study focuses on four research questions:

1) How did dental caries frequencies change through time? The samples were divided into Late Stone Age, Iron Age, or Recent. Each period was marked by a major shift in diet as new foods were introduced.

2) Is there a significant difference in caries between the sexes? The literature indicates a global trend for higher frequencies in females, particularly with the advent of agriculture (Caselitz, 1998; Lukacs and Largaespada, 2006; Lukacs, 2008; Lukacs and Thompson, 2008; Ferraro and Vieira, 2010). The present results will help test whether the trend holds in sub-Saharan Africa.

3) How do environmental differences affect the dental caries frequencies? Such differences limit what foods are present, so should have an influence. Samples are divided by the ecosystem from

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which they were derived: coastal, desert, savanna/grassland, and tropical rainforest.

4) How does subsistence strategy affect the caries rates? Sub-Saharan Africans used a range of strategies to procure food, including hunting and gathering, pastoralism, and agriculture. Because diet is determined by subsistence strategy there should be an impact. To address this likelihood and place sub-Saharan African peoples in broader spatiotemporal context, samples from the current study are compared to Turner’s (1979) meta-analysis of populations with different subsistence strategies.

Materials and Methods

Data on caries prevalence, as well as severity in some instances, were collected from 44 samples (n=2,119 individuals; 33,444 teeth, Table 1) throughout the African sub-continent by Irish during the course of his dental morphological research (1993, 1997). These samples date from ca. 10,000 BP to the 20th century.

The location and severity are recorded for each of the carious lesions present. Caries are ranked on a scale of 1 to 4, with 1 being a small pit that does not penetrate the enamel and 4 being pulp perforation (Buikstra and Ubelaker, 1994). Location is designated as mesial, distal, buccal, occlusal, lingual or a combination in the event of large or multiple lesions. Sex was determined as M, M?, ?, F, F? by the second author using standard methods (e.g., Buikstra and Ubelaker, 1994). Only adults (i.e., ≥18 years of age) were included in the analyses.

Lukacs’ (1992, 1996) caries index was calculated to adjust for antemortem tooth loss (AMTL):

\[(AMTL) = \frac{(\% \text{ teeth with severe caries}) + (\text{teeth with caries})}{(\text{teeth present}) + (\text{AMTL})}\]

This method takes into account the number of teeth present with pulp exposure (severity level 4) due to dental caries. The present study compares the percentage of teeth with carious lesions; therefore, results could be skewed if AMTL were not accounted for, since many teeth are removed due to toothache resulting from serious carious lesions or abscesses (Lukacs, 1996).

The caries data were compared using three common statistics. First, Mann-Whitney U and Tukey tests were used to compare the percent of teeth with carious lesions for the four major categories of independent variables (i.e., period, sex, environment, subsistence). Second, factorial ANOVA accounted for significant differences among subsistence strat-egy, environment, time period, between- sex, or any combination of these four on the dependent variable (percentage of teeth with caries per individual). The null hypothesis of consistency was tested, followed by a series of post hoc tests (i.e., Tukey) to identify significance between all combinations of the independent variables. Lastly, the Spearman’s Rho correlation coefficient was used to simply determine any relationship between attrition and caries. Higher levels of wear should correlate with fewer caries because normal attrition wears away the tooth surface before caries can form (Brothwell, 1963; Scott and Turner, 1988; Hillson, 1996; Caselitz, 1998).

Results

The Mann-Whitney U (Table 2) and Tukey (Table 3) test results show a statistically significant difference (p<0.05) for each pair of time periods. The factorial ANOVA found time period to be a significant factor for caries counts with a value of 0.005 (Table 4)

Mann-Whitney U (see Table 2), Tukey (see Table 3) and factorial ANOVA (see Table 4) tests show no statistically significant values for caries frequency differences between the sexes. However, the bar graph (Figure 2) does display a general trend of females with more carious lesions – at least for the Late Stone Age (LSA) and Iron Age samples. In the Recent samples males and females have equal percentages; the only significant difference is among pastoralists (not shown).

ANOVA (see Table 4) results show that environment has a significant impact on caries for the LSA (0.000), Recent (0.009), and Combined groups (0.004). The Mann Whitney U (see Table 2) results reveal no significant difference among environments in terms of caries counts for the Iron Age samples, but some differences do exist for LSA and Recent samples. Tukey (see Table 3) results show significant difference only among the LSA samples. Figure 2 illustrates the different counts of affected individuals for each environment category. Not all environmental categories are represented by time period; as such, some effect on results may occur and these should be interpreted with caution.

Factorial ANOVA (see Table 4) results suggest that subsistence contributes to caries counts for the Recent samples (0.060) and all periods combined (0.000). Outcomes from the Mann-Whitney U (see Table 2) and Tukey (see Table 3) tests show a difference between hunter/gatherers and pastoralists among the LSA samples (0.043) and hunter/gatherers and agriculturalists when all periods are
Table 1. Summary of samples including the current country the sample was collected from, the environment, time period, and subsistence strategy category the sample was found to best fit with, and the number of individuals from each sample.

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* information not available
Table 2. Results of Mann-Whitney U tests

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*significant at p<0.050

Table 3. Tukey results

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*significant at p<0.050

Table 4. Factorial ANOVA results

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<td>Environment</td>
<td>&lt;0.001</td>
<td>0.609</td>
<td>0.009</td>
<td>0.004</td>
</tr>
<tr>
<td>Subsistence</td>
<td>n/a</td>
<td>0.789</td>
<td>0.069</td>
<td>0.037</td>
</tr>
</tbody>
</table>

*significant at p<0.050

Figure 2. Percent of individuals affected by caries for each environment category in LSA, Iron Age, and Recent sub-Saharan African samples. See text for details.
combined (0.000). There is no significant difference in caries number between pastoralists and agriculturalists for any time period. Figure 3 visually represents the differences between subsistence strategies by time period.

Lastly, the correlation between wear and caries prevalence was calculated using Spearman’s Correlation Coefficient. The correlation of 0.012 indicates a very weak, yet positive relationship. An insignificant p-value of 0.400 was calculated.

Discussion

1) Did caries frequencies change through time?
Results show a definite increase in caries rate through time. Many new crops were introduced through time that may have had an impact. Asian sugarcane and bananas appeared as early as the Iron Age and via the Portuguese in the 17th century (Frencken et al., 1989; Irish and Turner, 1997). Sugarcane has a negative impact on health not only because of high sucrose levels but because of the manner in which it is eaten, which causes severe crown wear (Dreizen and Spies, 1952; Frencken et al., 1989; Irish and Turner, 1997). Bananas and plantains, both a significant crop in central and eastern Africa (Ehret, 2002), are moderately cariogenic due to their sticky and sugary structure (Mundorff-Shrestha et al., 1994; Aurore et al., 2008).

Several cariogenic crops from the Americas were also introduced, including maize and cassava (Larsen et al., 1991; Hillson, 1996; Ehret, 2002); most did not become widespread until the 18th century, which may account for the rise in caries between the Iron Age and Recent samples (Ehret, 2002). Overall, these soft, often sticky high carbohydate foods are much more cariogenic than the traditional African diet (Hillson, 2008).

2) Is the rate of caries higher among females than males?
All tests suggest that an individual’s sex did not significantly contribute to the caries frequencies; that said, an examination of the bar chart (Figure 1) reveals a general trend for higher frequencies in females. A common explanation for the disparity is that females collect, prepare and consume more cariogenic foods than do males (Mulder, 1992). Others potential causative factors include genetic and hormone differences; all are said to be accentuated in agriculturalist groups (Lukacs and Largaespada, 2006; Lukacs, 2008), though this is not evident in the present African samples—we are continuing to investigate.

3) Are there environmental differences in the caries frequencies?
Observing patterns is difficult because not all environmental groups are present by time period. In the Iron Age and Recent periods, caries are more prevalent among those on the savanna. Many of them would have relied on grain foods or pastoralism, i.e., the latter peoples often trade with agriculturalists for grains made into sticky porridge (Forde and Jones, 1950; Skinner, 1973). The naturally high cariogenicity of corn and wheat (Dodds, 1960; Okazaki et al., 2013) combined with the sticky nature of the grain porridge potentially contributes to higher instances of caries in savanna dwellers.

A high caries percentage (23%) occurs in coastal LSA samples. Coastal peoples generally have fewer caries because of grit and fluoride from marine foods (Walker and Erlandson, 1986). Sealy et al. (1992) report similar results with the Oakhurst sample from the Southern Cape. Contradictory to their results with other coast dwellers, where only 2.6% of teeth exhibit caries, 17.7% of teeth from Oakhurst are affected, despite a diet rich in marine resources; the authors state that the explanation for the high rate is the lack of fluoride in local ground water.

4) Does subsistence strategy affect dental health?
The results obtained by factorial ANOVA suggests that subsistence strategy is a contributing factor to caries counts when all time periods are combined. No clear pattern is evident in the bar chart (Figure 3), perhaps because not all strategies are present by period. However, the high rate for Recent pastoralists is interesting. As noted, pastoralists eat grains plus milk and other animal byproducts (Forde and

![Figure 3. Percent of individuals affected by caries for each subsistence strategy in LSA, Iron Age, and Recent sub-Saharan African samples. See text for details.](image)
Differences can have major implications for dental health. The results from the current study imply that cultural specializations, and food collecting strategies have been found to potentially affect dental decay. The introduction of new foods through time, regional migrations among 44 sub-Saharan, environmental groups, and subsistence strategies have frequencies been observed between time periods. Statistically significant differences in dental caries introduction of new foods through time, regional migrations among 44 sub-Saharan, environmental groups, and subsistence strategies have frequencies been observed between time periods. Statistically significant differences in dental caries have been found to potentially affect dental decay. The results from the current study imply that cultural specializations, and food collecting strategies have been found to potentially affect dental decay.

Conclusions
Statistically significant differences in dental caries frequencies have been observed between time periods, environmental groups, and subsistence strategies among 44 sub-Saharan African samples. The introduction of new foods through time, regional specializations, and food collecting strategies have been found to potentially affect dental decay. The results from the current study imply that cultural differences can have major implications for dental health.

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