

# Dental health of the late 19<sup>TH</sup> and early 20<sup>TH</sup> century Khoesan

D. Botha<sup>a\*</sup>, M. Steyn<sup>a</sup>

<sup>a</sup>Forensic Anthropology Research Centre, Department of Anatomy, University of Pretoria, Private Bag X323, Arcadia, 0007, Pretoria, South Africa.

\*Corresponding author. Tel.: 012-3194368, fax: 012-3192240. E-mail address: [deona.botha@up.ac.za](mailto:deona.botha@up.ac.za) (Deona Botha)

## Abstract

This paper presents the results of the dental analysis performed on a Khoesan skeletal sample representing the late 19<sup>th</sup> and early 20<sup>th</sup> century Cape Colony in southern Africa. Skeletal material from two European collections (Vienna and Paris) was selected to compile a total sample of 116 specimens. Dental pathology frequencies were calculated for caries (28.4%), antemortem tooth loss (37.9%), periapical abscesses (29.3%), periodontal disease (26.7%), calculus (44.0%) and impacted canines (4.3%). Attrition scores indicated that the group under study had an average rate of attrition compared to other southern African populations. Frequency and intensity data were compared to several other samples from both the pre-contact and contact phases by means of chi-squared analysis. The outcome of the study suggested that the group under study was most likely in a state of transition between a diet and lifestyle of hunting-and-gathering and agriculture. Results were also consistent with those of groups from a low socio-economic status.

## Introduction

Teeth are often available in archaeological specimens and because they are usually well preserved, they provide a relevant tool for bioarchaeological investigations. Numerous studies have been done on the reconstruction of diet and the vital role it plays in interpreting health and lifestyle of past populations (e.g., Cohen, 1989; Larsen, 2000; Lukacs, 1992; Morris, 1992; Sealy et al., 1992; Wols and Baker, 2004). Teeth are, just like bones, susceptible to changes related to diet and physiological stress. Unlike the bones of the skeleton, teeth are also vulnerable to cultural habits, i.e. dental modifications and food preparation techniques which may influence dental health (Alt and Pichler, 1998; Lukacs, 2012; Milner and Larsen, 1991).

The development of pathological dental processes is influenced by tooth crown morphology and size, occlusal surface attrition, food texture, age, nutrition, systemic disease and the presence of fluoride or other geochemical factors (Hildebolt et al., 1988; Leverett, 1982; Milner, 1984; Powell, 1985). The most common conditions encountered in archaeological/historical skeletal remains include caries, calculus formation, antemortem tooth loss, periapical abscesses, periodontal disease and attrition.

Several studies related to these pathological conditions in Khoesan populations have been published (Morris, 1992; Patrick, 1989; Sealy, 1989; Sealy et al., 1992). The majority of studies suggested that the frequency of dental pathology increased with the shift from a hunter-gatherer diet to an agricultural subsistence economy (Hillson, 1998; Klaus and Tam, 2010; Lukacs, 1992; Pechenkina et al., 2013; Roberts and Cox, 2003; Turner, 1979), as seen in many Khoesan groups. One should, however, keep in mind that inter-population variation will most certainly be present among different study results (Larsen, 1995, 2006). The establishment of an agriculturally based economy by the European colonists in the Cape during the 17<sup>th</sup>, 18<sup>th</sup> and 19<sup>th</sup> centuries initiated the introduction of refined carbohydrates to Khoesan people. As farm labourers, they often received rations of maize meal and sugar. Such refined foods have been proved to promote the development of caries, antemortem tooth loss and abscesses because they promote a cariogenic environment that is ideal for the growth of bacteria (Hillson, 1998; Lukacs, 1992; Oxenham et al., 2006; Pechinkina et al., 2013; Powell, 1985; Schneider, 1986). For example, Turner (1979) determined average frequencies for decayed teeth in three groups. Foragers had only 1.7% of teeth decayed, while mixed foraging and agriculture communities displayed an average of 4.8% decaying teeth. Purely agricultural groups showed the highest percentage of decayed teeth (8.6%). Antemortem tooth loss was more common in individuals suffering from caries, indicating that teeth may be lost due to decay or abscessing.

Although many Khoesan hunter-gatherers converted to an agricultural lifestyle during the colonization period by Europeans, some groups remained exclusively hunter-gatherers that had little or no contact with agricultural ways. Also, some individuals practised a mixed economic lifestyle in which they would collect food from the veldt, but also obtain food or water from farms during dry seasons (Tobias, 1959). As colonization progressed and free-roaming land available to the Khoesan diminished, more and more hunter-gatherer individuals changed from a foraging lifestyle to an agricultural subsistence economy, a process which occurred over the past 300 odd years. The diet of the Khoesan people at the

turn of the 20<sup>th</sup> century would have included meat and plants from the veldt, as well as agricultural foods.

The skeletal remains reported on here originated from the late 1800's and early 1900's southern Africa. The remains were collected from several locations as described by Botha and Steyn (2013). At the time, there was great demand for Khoesan skeletal material and curation of such remains by both local and international institutions reached a peak that resulted in the formation of several Khoesan skeletal collections in South Africa and Europe (Botha and Steyn, 2013; Legassick and Rassool, 2000). Many of the skeletal collections that came into being during this period most likely comprise specimens not belonging to one homogenous group, as skeletal material was collected over a vast geographical area from several different communities. However, social and political circumstances were uniform throughout the 19<sup>th</sup> and early 20<sup>th</sup> century southern Africa for all Khoesan individuals.

A complete palaeopathological analysis was performed for the study sample which has been published by Botha and Steyn (in print) that described the presence of infectious disease, nutritional disorders, degenerative disease, congenital abnormalities and trauma. The results indicated that the Khoesan group were of low socioeconomic status and that access to health care was limited.

The aim of this study was to assess the prevalence of dental pathological conditions in this sample of late 19<sup>th</sup> and early 20<sup>th</sup> century Khoesan individuals. This would provide more information on this phase in the history of the Khoesan of southern Africa that contributed to the end of their traditional way of life and integration into other societies.

## **Materials and methods**

A total of 116 Khoesan individuals from two European institutions were available for dental analysis, which included 46 males, 56 females and 14 individuals of unknown sex (including mostly juveniles for which it was difficult to assess sex). Fifteen individuals from the Musée de l'Homme skeletal collection in Paris (France), as well as 101 skeletons from the Rudolf Pöch collection in Vienna (Austria) were studied (Table 1). Demographic details regarding the skeletons from the Rudolf Pöch collection are described in a catalogue published by Pacher (1961). This reference was initially used as a guide when studying the remains. Skeletal analysis of all available material was done to confirm sex and age estimates provided in the catalogue. Detail regarding demographic data of these remains may be found in Botha and Steyn (in print).

**Table 1.** Summary of the sex distribution of the total skeletal sample.

	Males	Females	Unknown sex	Total
RP	41	48	12	101
MDH	5	8	2	15
Total	46	56	14	116

RP – Rudolf Pöch

MDH – Musée de l’Homme

All individuals were examined for signs of caries, antemortem tooth loss, dental wear, abscesses, periodontal disease, calculus and other dental pathologies.

The presence of dental caries was scored for all permanent teeth available. No reference was made to the position of caries on teeth. The data were then analyzed using calculations described by Lukacs (1989, 1995). This method involves calculating the individual caries frequency, caries intensity, mean number of carious teeth per individual (per mouth) and caries intensity per tooth type. Due to antemortem tooth loss, the intensity of caries in a population may be underestimated. It is therefore necessary to include a correction factor (Lukacs, 1995), which was done in this case.

The intensity of carious lesions was also divided by sex and tooth type to observe the difference between the sexes and to see if some teeth were more frequently affected than others.

Antemortem tooth loss (AMTL) was assessed in a similar manner (Lukacs, 1989). AMTL frequency, intensity, mean number of teeth lost per individual and prevalence of specific tooth types lost were calculated. Sex differences were also considered for all calculations.

Attrition was assessed using an eight point system designed by Molnar (1971). This method allows for scoring of all tooth types and is based on the various degrees of dentine exposure. The tooth types included incisors, canines, premolars and molars. All teeth present in an individual were assigned a number ranging from one to eight based on the abrasion of cusps and the appearance of dentine patches. The average rate of attrition for each tooth type was calculated for males and females, as well as for the total sample. A score of 1 indicated no wear, where as a score of 8 indicated that only the roots remained. Thus, the category of wear increased with the degree of attrition observed.

The presence of abscesses, periodontal disease, calculus and impacted teeth was recorded and the frequency and sex distribution within the sample were calculated for each condition. Although teeth were assessed for dental modifications, none were found.

The results were then compared to various other southern African groups to gain additional insight into the dental health of the study sample, as the interpretation of specific

pathologies is often a difficult task. These comparative samples included K2/Mapungubwe (Steyn, 1994), Riet River, Kakamas and Griqua (Morris, 1984; 1992), the Cobern Street, Marina Residence and Polyoak groups (Manyaapelo, 2007), as well as Bushmen (Drennan, 1929; Van Reenen, 1966) Oakhurst (Sealy et al., 1992), Maroelabult (Steyn et al., 2002) Koffiefontein (L'Abbé et al., 2003), Venda (L'Abbé, 2005) and Gladstone (Van der Merwe, 2006) samples. These groups represent the Later Stone Age with a traditional hunter-gatherer life style (Oakhurst), Iron Age with a mixed economy but before European contact (K2/Mapungubwe), contact phase groups (Riet River, Kakamas, Griqua, Cobern Street, Marina Residence, Polyoak; Drennan and Van Reenen data) and modern era individuals but roughly similar in age than the Khoesan individuals assessed in this study (Maroelabult, Koffiefontein, Venda and Gladstone). Koffiefontein and Gladstone represent early diamond mining communities, whereas the Venda group dates to the 20<sup>th</sup> century. The Maroelabult contains individuals from a farming community at the end the 19<sup>th</sup> and beginning of the 20<sup>th</sup> century from the interior of the country.

## **Results**

The results given here include frequency, intensity and comparative data of all conditions assessed.

### ***Caries***

As summarized in Table 2, 28.4% of individuals investigated presented with caries (Fig. 1). A total of 23.9% of males and 37.5% of females were affected. About 7% of individuals of unknown sex showed signs of caries. Males presented with an average of one carious lesion per mouth, whereas females had an average of two carious lesions per mouth. Also, 6.5% (111 teeth) of all teeth investigated (a total of 1722 teeth) were affected by caries. No significant difference was seen between males and females ( $\chi^2 = 2.164$ ;  $p = 0.1413$ ) for individual frequencies, but when calculating caries intensity (number of carious teeth/total number of teeth) a statistically significant difference ( $\chi^2 = 6.413$ ;  $p = 0.0113$ ) was seen between males and females. This means that a considerable number of females were not affected more than males by caries, but that females experienced a more intense and concentrated manifestation of caries than males. Although diet differences between males and females may have contributed to these results, it may not be labelled as the sole cause due to the absence of clear evidence showing that males and females followed remarkably different

diets. Other factors such as the role of hormonal fluctuations causing a more cariogenic biochemical composition of saliva in women (i.e., life history) and the role of agriculture in the development of these changes as described by Lukacs and Largaespada (2006), Ferraro and Vieira (2010) and Lukacs (2011) should be considered more plausible reasons for the difference in caries intensity between males in females seen in this study. These authors state that the underlying genetic mechanisms responsible for flow rate and composition of saliva, hormonal fluctuations, dietary habits and the development of agriculture may all play a role in contributing to higher caries intensity in women, making the etiology of caries complex and multifactorial.

**Table 2.** Summary of dental caries.

	Per individual <sup>1</sup>			Per mouth <sup>2</sup>			Per tooth <sup>3</sup>		
	n	NAI	%	NAI	NTA	C/m	NT	NTA	%
Male	46	11	23.9	11	37	1.0	781	37	4.7
Female	56	21	37.5	21	72	2.0	784	72	9.2
Unknown	14	1	7.1	1	2	0.0	157	2	1.2
Total	116	33	28.4	33	111	1.0	1722	111	6.5

1 – total number of individuals affected by dental caries / total number of individuals present

2 – total number of carious teeth / total number of individuals affected by dental caries

3 – total number of carious teeth / total number of teeth present

n – total number of individuals investigated

NAI – total number of individuals affected by dental caries

NTA – total number of teeth affected by dental caries

C/m – average number of carious lesions per mouth

NT – total number of teeth present



**Fig. 1.** Caries observed in the left mandibular molars of a young adult female (S115).

A corrected prevalence of caries was also calculated (Table 3) using the method described by Lukacs (1995). This was done to compensate for teeth lost antemortem due to caries, as caries is the leading cause of antemortem tooth loss. The results indicated a corrected caries prevalence of 8.7% for males (an increase of 4.0%), 14.1% for females (an increase of 4.9%) and 1.3% (an increase of 0.2%) for individuals of unknown sex.

**Table 3.** Corrected prevalence of caries.

Sex	AMTL	P	Ena	Ona	n	Ne	Ec	Ccr %
Male	202	0.24	48.5	37	781	983	85.5	8.7
Female	239	0.30	71.7	72	784	1023	143.7	14.1
Unknown	0	0.01	0.0	2	157	157	2.0	1.3
Total	441	0.26	114.7	111	1722	2163	225.7	10.4

AMTL – antemortem tooth loss

P – proportion of teeth that were lost antemortem due to caries (caries correction factor)

Ena – estimated number of teeth lost due to caries

Ona – number of carious teeth observed

n – number of teeth investigated

Ne – total number of teeth

Ec – estimated number of teeth with caries

Ccr% - caries correction rate

The caries intensity (not corrected) was also calculated for tooth type and sex. Males and females showed similar patterns in terms of the tooth type affected. The molars were mostly affected, with M2 showing the highest intensity (11.2% overall), followed by the premolars (PM1 = 5.4%; PM2 = 6.4%). The incisors and canines were affected to a lesser degree, with I2 being the least affected (1.7%) of all the tooth types. Chi-squared analysis between males and females for specific tooth types showed that a statistically significant difference ( $\chi^2 = 9.51$ ;  $p = 0.0020$ ) was observed only in the premolars, with females affected more than males. When assessing caries frequency, it was noted that the frequency of the current sample is quite different from that of the other populations. Chi-squared analysis performed for caries intensity revealed that there is a statistically significant difference between the current study group and all the other comparative samples, except Griqua, Venda and Maroelabult (Table 4). The chi-squared results indicated that the caries intensity of the current study sample is most similar to groups of mixed economy such as the Griqua, and thus higher than that encountered in the hunter-gatherer groups, but less than seen in the agricultural populations. The only exception here is in the material from Oakhurst, a hunter-gatherer group with an exceptionally high caries frequency. The authors (Sealy et al., 1992) attributed this to the low fluoride content in the drinking water from Oakhurst, that produced exceptional vulnerability to caries.

**Table 4.** Carious lesions in the current sample and other South African samples.

Population	n	Na	Nt	Nta	Caries frequency (%)	Caries intensity (%)	Cariou teeth/mouth	Chi <sup>2</sup> *	p-value	Source
Current study	116	33	1722	111	28.4	6.5	1.0	-	-	This study
Gladstone	92	51	2694	116	55.4	4.3	2.8	9.86	0.0017**	Van der Merwe (2006)
Riet River	46.5 <sup>a</sup>	-	1061	46	41.7	4.3	1.0	5.49	0.0191**	Morris (1992)
Kakamas	42.5 <sup>a</sup>	-	989	13	18.8	1.3	0.3	37.91	<0.0001**	Morris (1992)
Griqua	26	-	575	30	42.3	5.2	1.2	1.13	0.2876	Morris (1992)
Oakhurst	13	11	192	34	84.6	17.7	4.0	31.27	<0.0001**	Sealy et al. (1992)
“Wild Bushmen”	104	-	3335	17	7.7	0.5	0.2	162.19	<0.0001**	Van Reenen (1966)
“Farm Bushmen”	221	-	7052	56	12.2	0.8	0.3	236.73	<0.0001**	Van Reenen (1966)
Colesberg Bushmen	53	-	1211	32	22.6	2.6	0.7	22.18	<0.0001**	Drennan (1929)
Venda	97	59	2016	157	60.8	7.8	1.6	2.51	0.1131	L’Abbé (2005)
Maroelabult	23	13	582	26	56.6	4.5	2.0	3.05	0.0807	Steyn et al. (2002)
K2/Mapungubwe	-	-	306	56	54.5	18.3	1.4	48.31	<0.0001**	Steyn (1994)
Cobern Street	28	21	734	118	75.0	16.1	4.2	56.45	<0.0001**	Manyaapelo (2007)
Marina Residence	32	27	759	120	84.4	15.8	3.8	54.71	<0.0001**	Manyaapelo (2007)
Polyoak	9	7	210	57	77.8	27.1	6.3	101.01	<0.0001**	Manyaapelo (2007)

n = number of individuals investigated

Na = number of individuals affected

Nt = total number of teeth investigated

Nta = number of teeth affected by caries

<sup>a</sup>Individuals with only a mandible/maxilla account as one half of one individual (Morris, 1992)

\*degrees of freedom = 1

\*\*statistically significant difference observed



The study group's diet thus most likely contained a fair amount of carbohydrates that promoted caries, as often encountered to a large extent in agricultural subsistence groups. It is also likely that for certain periods they might have relied on hunting for subsistence, during which meat would have formed the greater part of their diet, contributing to a decrease in caries intensity.

### ***Antemortem tooth loss***

AMTL affected 19 males and 25 females (Table 5). An average of 10.6 and 9.5 teeth were lost antemortem per mouth in males and females, respectively. No teeth were lost antemortem in individuals of unknown sex. An AMTL intensity of 13.7% was seen in males, whereas females showed an intensity of 13.3% (not statistically significant:  $\chi^2 = 0.114$ ;  $p = 0.7356$ ).

**Table 5.** Summary of antemortem tooth loss (AMTL).

Sex	n	Per individual <sup>1</sup>		Per mouth <sup>2</sup>			Intensity <sup>3</sup>		
		Nai	%	Nai	Na	C/M	Nt	Na	%
Male	46	19	41.3	19	202	10.6	1472	202	13.7
Female	56	25	44.6	25	239	9.5	1792	239	13.3
Unknown	14	0	0	0	0	0	448	0	0
Total	116	44	37.9	44	441	10.0	3712	441	11.9

1 – total number of individuals affected by antemortem tooth loss / total number of individuals investigated

2 – total number of teeth lost antemortem / total number of individuals affected by antemortem tooth loss

3 – total number of teeth lost antemortem / total number of tooth places present

n – total number of individuals investigated

Nai – number of individuals affected by antemortem tooth loss

Na – number of teeth lost antemortem

C/M – average number of teeth lost antemortem per mouth

Nt – total number of tooth places present in the sample

In general, the incisors and molars showed the highest incidence of AMTL. In males, the first incisor was the tooth most commonly lost antemortem, whereas females showed the highest AMTL intensity for the third molar. This pattern would suggest different mechanisms of tooth loss in males in females. In the men, trauma and possibly interpersonal violence may have played a role, whereas in females caries was most probably the main cause of teeth loss. One should also take into consideration that tooth modification (i.e. removal of the central and lateral upper incisors seen in coloured groups from the Cape) could have contributed to AMTL in the current population. A statistically significant difference was seen only in the second molar ( $\chi^2 = 4.41$ ;  $p = 0.0358$ ), with females more affected than males.

The incidence of AMTL in the present study as compared to that of various other South African populations is summarized in Table 6. The results of the present study were found to

be similar to that of the Marina Residence and Polyoak samples. The Griqua and Venda groups presented with a higher AMTL intensity than the current group, whereas the Riet River, Kakamas, Gladstone, Koffiefontein and Cobern Street groups presented with lower AMTL intensities. A statistically significant difference was observed between the current group and all comparative samples, except Marina Residence and Polyoak.

**Table 6.** Antemortem tooth loss in various other South African samples.

Population	n	Na	AMTL intensity (%)	Chi <sup>2</sup> *	p-value	Source
Current study	3712	441	11.9	-	-	This study
Gladstone	2694	63	2.3	195.94	<0.0001**	Van der Merwe (2006)
Riet River	1557	95	6.1	40.09	<0.0001**	Morris (1992)
Kakamas	1317	54	4.1	66.31	<0.0001**	Morris (1992)
Griqua	894	152	17.0	17.10	<0.0001**	Morris (1992)
Venda	2016	347	17.2	31.31	<0.0001**	L'Abbé (2005)
Koffiefontein	1016	63	6.2	27.02	<0.0001**	L'Abbé <i>et al.</i> (2003)
Cobern Street	849	61	7.2	15.55	<0.0001**	Manyaapelo (2007)
Marina Residence	885	104	11.8	0.00	0.9496	Manyaapelo (2007)
Polyoak	263	27	10.3	0.62	0.4310	Manyaapelo (2007)

n – total number of tooth places present

Na – total number of teeth lost antemortem

\*degrees of freedom = 1

\*\*statistically significant difference observed

### ***Attrition***

The maxillary teeth of 19 males and 20 females were scored for dental wear, whereas the mandibular teeth of 17 males and 20 females were assessed.

When pooling male and female values, the highest average scores in the maxilla were seen in the central and lateral incisors. However, in the mandible, the central incisors and first molars showed the most severe signs of attrition. In both the maxilla and mandible, as well as for male and female values, the third molars were the least worn of all tooth types inspected.

In the maxilla, the average scores for all tooth types proved to be higher in females than in males. However, in the mandible average dental wear scores in females exceeded those of males in the central incisor, lateral incisor, second premolar, first molar, second molar and third molar. In general, a greater amount of dental wear was seen in females than in males.

Comparison of the results is given in Table 7. The method used for scoring attrition (eight point scoring system described by Molnar, 1971) is the same for the present study, K2/Mapungubwe, Cobern Street, Marina Residence and Polyoak groups. The Riet River, Kakamas and Griqua groups, however, were analysed by Morris (1984) using a scoring system adapted from Brothwell (1963). Steyn (1994) calculated corresponding values for

these three groups in order to compare it to the K2/Mapungubwe population. These adapted values were used in this study for comparison to the current sample.

**Table 7.** Comparison of average molar attrition values for various South African samples.

Population	n	Average attrition	Source
Current study	39	3.8	This study
K2	18	4.0	Steyn (1994)
Mapungubwe	5	3.2	Steyn (1994)
Riet River	51	2.4 (~4)*	Morris (1984)
Kakamas	43	2.1 (~3)*	Morris (1984)
Griqua	26	1.6 (~2)*	Morris (1984)
Cobern Street	28	3.5	Manyapelo (2007)
Marina Residence	36	3.5	Manyapelo (2007)
Polyoak	10	4.0	Manyapelo (2007)

n – number of individuals scored

\*values in brackets are the adapted values by Steyn (1994) to correspond with the Molnar (1971) scoring system

Attrition for the group under study appears to be average when compared to other South African groups, having an average value less than that of the Riet River, K2 and Polyoak samples, but high in comparison to the Kakamas, Griqua and Mapungubwe groups.

### **Dental calculus**

A summary of dental pathologies, including dental calculus, periodontal disease, abscesses and impacted canines, is given in Table 8.

A total of 51 (44.0%) individuals were found to have calculus deposits. Of these individuals 25 (54.4%) were male and 26 (46.4%) were female. Dental calculus was not noted in any individuals of unknown sex. There was no statistical significant difference between males and females ( $\chi^2 = 0.634$ ;  $p = 0.4259$ ).

**Table 8.** Frequency of other dental pathologies present in the current sample.

Pathological condition	Male (n = 46)		Female (n = 56)		Unknown (n = 14)		Total (n = 116)	
	Na	%	Na	%	Na	%	Na	%
Tartar deposition	25	54.4	26	46.4	0	0	51	44.0
Periodontal disease	15	32.6	16	28.6	0	0	31	26.7
Abscesses	13	28.3	21	37.5	0	0	34	29.3
Impacted canines	2	4.4	3	5.4	0	0	5	4.3

n – total number of individuals investigated

Na – number of individuals affected by the condition

The Gladstone sample (Van der Merwe, 2006) also presented with considerable dental calculus. A total of 32.2% of individuals investigated showed positive signs of tartar deposition. Mosothwane (2004) reported an incidence of 26.1% among all Toutswe individuals investigated for calculus deposits. An incidence of 78.3%, 84.0% and 40.5% were calculated for the Cobern Street, Marina Residence and Polyoak groups, respectively

(Manyaapelo, 2007). The Khoesan displayed a tartar frequency similar to that of the Polyoak group, but presented with an incidence almost half that of the Cobern Street and Marina Residence. The current study did, however, had a higher frequency of calculus than seen in the Gladstone and Toutswe samples. This suggests that the current study group had a high incidence of dental calculus, with almost half of all scorable individuals affected.

### ***Periodontal disease***

Fifteen adult males (32.6%) and 16 adult females (28.6%) that totalled to 31 (26.7%) individuals were found to have suffered from periodontal disease. No individuals of unknown sex were affected by this condition. There was no statistically significant difference between males and females ( $\chi^2 = 0.195$ ;  $p = 0.6588$ ).

Periodontitis (Fig. 2) was also reported in 39.5% of the Gladstone sample (Van der Merwe, 2006). This condition was not reported on in the other comparative samples used for this study. The present study showed a lower incidence of periodontal disease than seen in the Gladstone sample. Poor oral hygiene is most likely to blame for this condition occurring in the Khoesan. However, periodontitis in the Gladstone population was probably due to the combination of poor oral hygiene and the presence of scurvy, accounting for the higher incidence of periodontal disease seen in this mining community.



**Fig. 2.** Periodontal disease around the mandibular teeth of a middle aged adult male (S22).

### *Abscesses*

Periapical abscesses (Fig. 3) were noted in 34 (29.3%) of individuals investigated. Of these 13 (28.3%) were male and 21 (37.5%) were female. No individuals of unknown sex presented with abscesses. No significant difference was observed between males and females ( $\chi^2 = 0.967$ ;  $p = 0.3254$ ).



**Fig. 3.** Abscess of the maxillary right first molar in a middle aged male (S18).

Abscesses were also noted in 14.4% of the Gladstone sample (Van der Merwe, 2006), as well as in 7.2% of the Venda sample (L'Abbé, 2005). A frequency of 32.1%, 33.3% and 44.4% were reported for the Cobern Street, Marina Residence and Polyoak groups, respectively. The present study showed a frequency of abscesses similar to that of Cobern Street and Marina Residence, which suggests that the current study group were also following diet and oral health patterns often seen in poor communities, as reported for Cobern Street and Marina Residence (Manyaapelo, 2007).

### *Impacted canines*

Impacted permanent canines (Fig. 4) were seen in two males (4.4%) and three females (5.4%). No individuals of unknown sex were affected by this condition. This condition occurs

due to a disturbance in the normal eruption pattern of permanent teeth. The underlying cause is believed to be genetic and the product of polygenic, multifactorial inheritance. Also, it is almost always encountered bilaterally (Peck et al., 1994). All individuals affected displayed bilateral impacted canines. Both males (S24, #3582), as well as one female (S101) had impacted canines in the maxilla. The remaining two females (S52, C15) displayed impacted canines in the mandible. All individuals were adult, except for individual #3582, which had been an adolescent.



**Fig. 4.** Impacted maxillary canines in a young adult female (S101).

The Kouga mummy (Steyn et al., 2007) also showed impaction of the maxillary canines. The presence of this phenomenon in both an archaeological case of a Khoesan individual and in a historic group (the current study) suggests that the occurrence of impacted canines may not be an unusual feature in the Khoesan people and that it likely has a genetic origin.

## **Discussion**

The results of the current study, as well as the archaeological literature suggest that Khoesan hunter-gatherers and pastoralists were gradually influenced by agricultural subsistence in the Cape Colony. Subsequently, behavioural changes caused an increase in the intensity of dental pathological conditions throughout the general population.

The higher intensity of caries in the current sample (6.5%) when compared to hunter-gatherer groups, such as Riet River (4.3%), Kakamas (1.3%), Colesberg (2.6%) and Bushmen groups (“wild” bushmen, 0.5%; “farm” bushmen, 0.5%) studied by Van Reenen (1966) can be expected, as this sample is heterogenous and comprises individuals from both hunter-gatherer and agricultural lifestyles – in essence a population in transition. The diet of hunter-gatherers contains very few sugars and refined carbohydrates, which decreases their risk of developing caries (Cohen and Armelagos, 1984; Lukacs, 1990; Morris, 1992). It is thus likely that the caries intensity observed in this study reflects a diet that contained more carbohydrates than found in the typical hunter-gatherer diet.

It was also noted that the caries intensity for this study was less than that reported for Cobern Street, Marina Residence and Polyoak (Manyapa, 2007). A significant difference was observed between the current sample and all three of these groups. Sugar, refined milled flour and maize meal were common dietary products used throughout the seventeenth and eighteenth centuries in the Cape (Morris, 1992). The skeletal samples from Cobern Street, Marina Residence and Polyoak typically reflect a diet rich in carbohydrates, as they worked near the harbour and on colonial farms. As many Khoesan individuals have been employed by colonists, their diets were most likely supplemented with some form of refined carbohydrates, resulting in an increase in caries intensity. However, many remained hunter-gatherers, who had very little access to refined carbohydrates such as sugar. The results thus portray that of a mixed group that contains both individuals of poor and excellent dental health, and reflects the changes that were occurring during that time period in the Khoesan in general.

The prevalence of caries in this study was found to be most similar to that of the Griqua and Venda. The Griqua has been described as a population of mixed economy, bearing anatomically heterogenous features. The Griqua diet most likely included meat from hunting and maize meal as staple food, as their social and economic circumstances were quite different from those of hunter-gatherers, such as Riet River, Kakamas and Colesberg, which who most likely survived mainly on meat and veldt plants (Morris, 1992). They are most likely the group that can be described as being most similar to the current study sample in terms of social and economic circumstances. These results parallel those of Turner’s study (1979) in which it was reported that caries frequencies of hunter-gatherers were less than 2% (such as Riet River and Kakamas), mixed economies about 5% (such as Griqua) and agricultural economies more than 10% (such as K2/Mapungubwe and Polyoak). The current

study sample thus appears to have been in transition between the traditional hunter-gatherer diet and a more modernized diet used by agricultural groups.

When considering caries intensity sorted by tooth type the molars were affected the most, which is generally the most common pattern (Hillson, 1998). The premolars were second most affected, followed by the canines and incisors. The incisors have been reported to be affected more commonly than the canines (Hillson, 1998), however, in this case the incisors were least affected. The reason for this is not clear, although it may be related to some activity performed by the females of this group, as the caries intensity of the canine for females were found to be higher than that seen in males. No statistically significant difference was seen between males and females with regard to caries intensity in the canine teeth. A significant difference was, however, seen between males and females for caries occurring in the second premolar. In general, the diet of males and females appears to have been very much alike, as a significant difference was only observed for one tooth type.

The results from this study indicate that the population experienced a relatively high AMTL intensity. Several factors have possibly contributed to almost 38% of individuals experiencing AMTL. Firstly, the presence of carious lesions (found in about 28% of individuals) most likely caused AMTL as these lesions tend to increase in size, destroying teeth. Secondly, periodontal disease was observed in almost 27% of adult individuals. In severe cases this would have caused AMTL. Thirdly, a high degree of attrition was observed in the study sample, which would have made teeth more vulnerable to abscesses due to dentine exposure that may have resulted in AMTL.

The molars and incisors were mostly affected when considering AMTL sorted by tooth type. The molars are often more frequently affected by caries than the other teeth, as more crevices and fissures are present for plaque to adhere to and promote carious activity (Bonfigliolo et al., 2003). This suggests that molars were most likely lost due to carious lesions. However, incisors may have been lost not only due to caries, but also due to wilful extraction of incisors performed as a cultural ritual, which is known as the “passion gap” amongst the Cape Coloured people (Allen et al., 1990; Friedling and Morris, 2005, 2007).

Furthermore, it is possible that males experienced more interpersonal violence causing loss of the anterior teeth than females, hence the fact that the first incisors were most frequently lost in males. In females, it is likely that caries were the main contributing factor to AMTL, as the third molar was most frequently lost.

When comparing the results to other South African samples, it was noted that the current study group had an AMTL intensity similar to that of Marina Residence and Polyoak



(Manyapa, 2007), but was significantly different from all other comparative groups (L'Abbé et al., 2003; L'Abbé, 2005; Morris, 1992; Van der Merwe, 2006). Both the Griqua and Venda samples showed a higher AMTL intensity than the study sample. The Griqua sample portrayed a low attrition rate, suggesting that a high caries rate and/or dental trauma were most likely to blame for their high intensity of AMTL. Unfortunately, no data are available on dental attrition for the Venda sample, but degenerative dental changes due to old age, dental mutilation and wilful extraction of teeth have been mentioned as possible causes of the relatively high AMTL intensity observed in this group (L'Abbé, 2005).

AMTL in the current study was also found to be much higher than that of Riet River and Kakamas, but this is as expected, since both of these hunter-gatherer groups had a low caries intensity. Gladstone also had an AMTL intensity much lower than that of the current sample, but this may possibly be attributed to the young age of the individuals from Gladstone.

It can be concluded that AMTL in the Khoesan population studied here are multifactorial, and can most probably be associated with the loss of teeth due to large carious lesions resulting in tooth destruction, the presence of periodontal disease, severe attrition, possible intentional removal of the incisors and trauma.

The degree of wear is often associated with the culture of a population and tends to decrease from prehistoric to modern populations as the sophistication of food preparation and production methods in modern times resulted in more refined foods (Brothwell, 1963; Molnar, 1971). Different populations also tend to show different wear patterns, depending on cultural practices and the use of teeth as tools (Hinton, 1981; Scott and Turner, 1988).

In general, the central incisors, in both the maxilla and mandible of the Khoesan under study, displayed the highest degree of wear. The second and third molars showed the least amount of wear. These results are consistent with the findings of Van Reenen (1966, 1982), in which he reported that the anterior teeth of the Kalahari San showed a higher degree of attrition than the posterior teeth. Additionally, in the current study the use of the anterior teeth as possible tools may have resulted in reduced crown height of the upper and lower incisors. It is possible that the anterior teeth were used for stretching and softening of animal skins in the process of making clothes, or other similar activities.

Attrition rates of males and females were similar, except in the maxillary central incisors, for which females showed a higher degree of wear than males. Sex differences in crown wear differ between populations and each population should be investigated within its own biological and cultural context in order to discover the reason behind male and female discrepancies (Littleton et al., 2013; Scott and Turner, 1988). It is possible that in our study

females used their central incisors as tools more often than males for a specific activity, such as making clothes from animal skins or stripping peels of vegetables/plants (Berbesque et al., 2012).

When comparing the rate of attrition of the current study group to that of other South African groups, it was found that the results were similar to that of all groups, except the Griqua that showed a much lower degree of wear. The dental wear rates of archaeological samples such as K2 and Mapungubwe are similar to those of hunter-gatherers (such as Riet River and Kakamas) and may be explained by the high amount of abrasive material found in their food (El-Zaatari, 2010; Steyn, 1994).

Since it is not uncommon for hunter-gatherers to have a great degree of dental wear due to the unrefined nature of their food (Scott and Turner, 1988; Scott et al., 2006), it can be concluded that the Khoesan group examined in this study showed a relatively high degree of dental wear which is consistent with attrition rates observed in hunter-gatherer populations. Also, the use of the anterior teeth as tools may have contributed to more advanced wear being observed in the anterior than posterior teeth.

The presence of other dental pathologies including tartar deposition, periodontal disease, abscesses and impacted canines suggest that little dental hygiene was practised. A relatively high frequency of tartar deposition indicated that their diet likely included a fair amount of proteins or meat. It has been reported that tartar deposition is often greater in populations that follow a protein-rich diet that contains very little or no carbohydrates, such as seen in hunter-gatherers (Eshed et al., 2006; Lillie, 1996). Also, as many individuals are mature adults, a build-up of calculus most likely occurred as seen in some of the individuals. The frequency of tartar deposition in this study is higher than that of the Gladstone sample in which the lower frequency of calculus has been ascribed to the young age of the individuals (Van der Merwe, 2006).

Periodontal disease has been shown to have a strong correlation to age, although it can be significantly influenced by dental hygiene and general dietary practices (Axelsson et al., 2004; Larsen, 1995; Scott and Turner, 1988). It has been suggested that this disease is over-diagnosed in skeletal samples, as this condition may develop merely due to the body compensating for extreme attrition, and is thus not always the result of disease or nutritional deficiency (Roberts and Manchester, 2005).

A study by Leigh (1925) stated that hunter-gatherers portrayed less periodontal disease than people from mixed economies, while individuals practicing agricultural economies showed the highest frequency where generalized resorption affected all teeth. Similar

findings have been reported by other authors (Larsen, 1995; Polo-Cerdá et al., 2007) supporting this statement. The results of the current study are consistent with a mixed economy as described in Leigh's study, as periodontal disease was not observed as a generalized trend that affected all teeth, but were encountered more frequently than expected in a typical hunter-gatherer population.

A possible explanation for agricultural communities experiencing higher frequencies of periodontal disease than hunter-gatherer groups may be found in the difference in diet between the two subsistence economies. Periodontal disease is often associated with an insufficient amount of vitamin C in the diet of a population, although skeletal signs such as haemorrhaging, indicating the full onset of scurvy, may be absent as periodontal disease may reflect only mild vitamin C deficiency or may present as an early sign of scurvy (Brickley and Ives, 2006; Lavigne and Molto, 1995). Agricultural communities' diet often contains few fresh produce, but large amounts of maize as a staple food, with the occasional addition of meat. Their diet is often lacking in sufficient levels of vitamin C, which promotes the development of periodontal disease (Larsen, 1997; Van der Merwe et al., 2009). Hunter-gatherer populations, however, use a wide range of plant species and include a few bush foods that are exceptionally rich in vitamin C, such as morula fruit and baobab flesh (Tanaka, 1976; Truswell and Hansen, 1976). A population of mixed economy, such as seen in the present study, would thus be more prone to developing periodontal disease than populations solely following a hunter-gatherer lifestyle.

Abscess frequency was similar to that of periodontal disease observed in the study sample. Although the rate at which abscesses occur in different subsistence economies does not always differ significantly, the causes as to the development of abscesses may vary (Scott and Turner, 1988). Severe attrition and carious lesions are almost always to blame, but dental trauma may also play a role in populations that exhibit dental mutilation (Hillson, 1998; Molnar, 2008; Ortner, 2003).

The development of abscesses in the current study group is most likely due to large carious lesions, severe attrition and poor dental hygiene. No dental mutilation of teeth was encountered and can thus not account for abscesses observed in the area of the incisors and canines.

In conclusion, the results indicated that the study group's diet and dental health was not consistent with either a hunter-gatherer or agricultural economy, but reveal a group in transition between the two subsistence economies. The results indicated that dental pathology (i.e. caries and antemortem tooth loss) was affected not only by the incorporation of

carbohydrates in their diet, but also by a high degree of attrition, poor dental hygiene and the absence of dental health care.

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