Health and demography in late 19th century Kimberley : a palaeopathological assessment

Merwe, A.E. van der
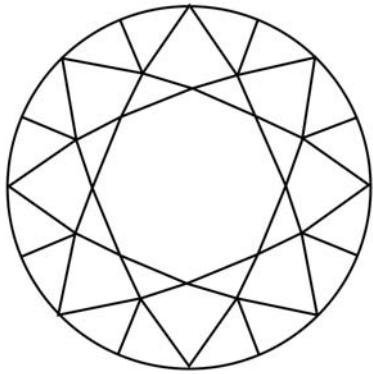
CHAPTER **5**

Adult Scurvy in Skeletal Remains of Late 19th Century Mineworkers from Kimberley, South Africa

Inside Wesselton Mine compound
(McGregor Museum Kimberley Photography nr.564)
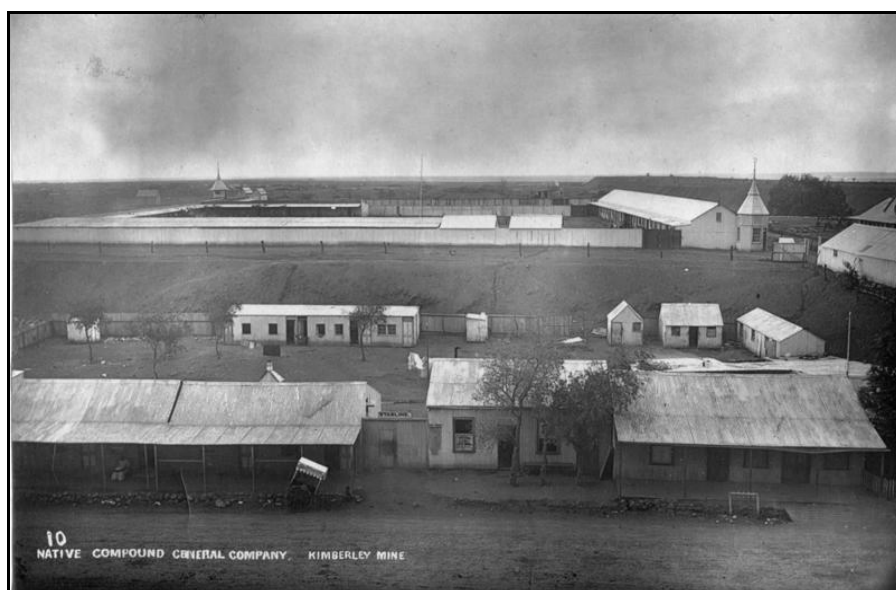
Central Company Compound, Kimberley
(McGregor Museum Kimberley Photography nr.9426)

Abstract

Throughout history, scurvy has been a well-known disease that develops due to restrictions on fresh fruit and vegetable resources. The condition results from an extended limited intake of vitamin C. Although skeletal lesions associated with infantile scurvy have been well described by many authors, very little literature is available on adult scurvy and the resulting skeletal lesions. The purpose of this study was to investigate the skeletal remains of a 19th century mining population from Kimberley, South Africa, for any skeletal lesions that may be indicative of adult scurvy. Scurvy was well documented as being extremely prevalent in this population. The skeletal remains of 107 individuals, presumed to have died around 1898, were studied. The majority of these individuals were males between 20 and 49 years of age. It is likely that most individuals were migrant diamond mine workers. All bones were visually assessed for macroscopic indications of pathological bone alterations associated with healed scurvy. Bone samples were also taken from ambiguous lesions in order to perform histological investigations. Lesions indicative of possible healed adult scurvy were observed in 16 individuals. These lesions included bilateral ossified haematomas, widespread subperiosteal bone reactions and periodontal disease. Histological investigation confirmed the presence of ossified haematomas on the anterior tibiae of some individuals. Hospital records and historical documents describing the prevalence of scurvy in the local hospitals and the daily diet of the black mine workers supported these findings.

5.1 Introduction

Scurvy has been recognised as a serious disease in history, resulting in many deaths due to limited fresh vegetables and fruit during periods of poverty, war, famine or long journeys (Steinbock, 1976; Reuler *et al.*, 1985; Pangan & Robinson, 2001; Maat, 2002; De Luna *et al.*, 2003; Ortner, 2003; Fain, 2005). The condition results from an extended limited intake of vitamin C, also known as ascorbic acid. Ascorbic acid is responsible for the hydroxylation of lysine and proline in the body and is therefore an essential element during the synthesis of polypeptide precursors for the formation of collagen fibrils. A deficiency in vitamin C causes collagen abnormalities (Steinbock, 1976; Stuart-Macadam, 1989; Ortner & Ericksen, 1997; Pangan & Robinson, 2001; Ortner, 2003; Fain, 2005; Brickley & Ives, 2006). Accordingly, clinical abnormalities include abnormal dentine production, weakening of the blood vessel walls and a tendency to develop haemorrhage, oedema, purpura, tooth loss, bone changes and keratin abnormalities (Pangan & Robinson, 2001; De Luna *et al.*, 2003; Ortner, 2003; Fain, 2005).

Vitamin C cannot be produced in the human body and therefore, the regular intake of this vitamin is essential (Stuart-Macadam, 1989; Fain, 2005; Brickley & Ives, 2006). At least 10mg of vitamin C should be consumed every day in order to prevent deficiency (Reuler *et al.*, 1985; Pangan & Robinson, 2001; Fain, 2005). The best natural sources of vitamin C are citrus fruits and uncooked green vegetables. Large amounts of potatoes and meat, such as liver and kidney, can also provide sufficient levels of ascorbic acid (Steinbock, 1976; Roberts & Manchester, 1995; De Luna *et al.*, 2003; Fain, 2005; Brickley & Ives, 2006).

Pathological changes associated with scurvy have been well described in the clinical literature. Apart from gingival hypertrophy and bleeding, petechiae (pinpoint bleeding of the skin) and follicular hyperkeratosis, haematoma formation and subperiosteal swellings in the lower extremities have been reported (Petit, 1741; Hamilton & Dyke, 1918; Hirschmann & Raugi, 1999; Fain, 2005). Haematoma formation on the tibiae in particular was noted by Aschoff and Koch (1919), who examined and dissected 23 soldiers who suffered from scurvy. Although skeletal lesions associated with infantile scurvy have been well described by many authors such as Stuart-Macadam (1989), Ortner and Ericksen

(1997) and Brickley and Ives (2006), very little literature is available on adult scurvy and the resulting skeletal lesions (Van der Merwe, 2007).

A study conducted by Maat (1984) provided some insight into the development, and specifically the distribution, of lesions in adult scurvy. In this study the remains of 50 Dutch whalers were investigated (Maat, 1984; Maat & Uytterschaut, 1987; Maat, 2004). Historical records indicated that scurvy had been a major problem among the men who participated in the whaling expeditions and lesions suggestive of scurvy were found in 39 of the 50 individuals (Maat, 1984). These lesions included signs of subperiosteal haematomas, haemarthroses and periodontal bleeding (Maat, 1984; Maat, 2004). It was found that subperiosteal haematomas often affected the diaphyses of the tibiae and fibulae and that these lesions were usually bilateral (Maat, 1984). However, in cases where haematomas were observed on the upper extremities, lesions were frequently unilateral. It should be mentioned that the individuals investigated in this study were extremely well preserved and diagnosis was made mainly on the basis of visible soft tissue remnants of haemorrhage.

However, this study, gave important insights into the distribution of lesions that can be associated with adult scurvy. Unfortunately, only one individual in this sample presented with bony lesions associated with healed vitamin C deficiency. This is understandable when considering that the whalers died in a scorbutic state and skeletal lesions associated with scurvy would only develop once normal vitamin C levels had been restored (Murray & Kodicek, 1949).

The purpose of this study was to investigate the skeletal remains of a 19th century mining population from Kimberley, South Africa, for lesions indicative of scurvy. Scurvy was well documented in historical records describing the study population. The condition was extremely prevalent and resulted in numerous deaths among the migrant labourers working in Kimberley (Medical Officer of Health, 1900).

5.2 Materials and Methods

In April 2003, the Sol Plaatjie Municipality (Kimberley) unknowingly disturbed several unmarked graves outside the fenced Gladstone Cemetery while digging a proposed storm-water trench. The McGregor Museum in Kimberley became involved through the

South African Heritage Resources Agency (SAHRA), and was requested to exhume and investigate the graves. After the excavation, all skeletal material and artefacts, were taken to the McGregor museum, tagged, and kept for further analysis.

It is likely that most individuals within this population were migrant workers, as was suggested by historical reports. Native individuals in search of work flooded into Kimberley during the late 19th Century after diamonds had been discovered in the area (Leary, 1891; Stoney, 1900; McNish, 1970; Roberts, 1976; Jochelson, 2001). Men left their families at home (whether in another town or another country) and came to Kimberley in the hope of finding fortune or maybe merely an extra income to sustain their families (McNish, 1970). When they became ill these individuals were treated in the Kimberley and compound hospitals (Van der Merwe, 2007). Various diseases such as tuberculosis, treponematosis, scurvy and cases of violent injury, to name but a few, were described in historical documents from these hospitals. In the case of death, the patients received a pauper's burial, as no direct family could be contacted. It should be noted that Kimberley was a rapidly growing city with limited resources. It was the first city in South Africa to develop away from a natural water source, and this, in conjunction with the extremely dry climate, had severe consequences on the availability of fresh fruit and vegetables (Roberts, 1976).

Standard anthropometric techniques such as cranial morphology, the width of the pubic angle, morphological changes of the sternal ends of the ribs and discriminant functions were used to determine the age and sex of all individuals exhumed from the trench (e.g. De Villiers, 1968; Krogman & İşcan, 1986; Hillson, 1998; Oettlé & Steyn, 2000; Asala, 2001; Franklin *et al.*, 2005). A total of 107 skeletons were excavated, including 86 males, 15 females and 6 individuals of unknown sex. The majority of individuals excavated from the trench were young and middle-aged adults, as can be seen in Table 5.1. One premature baby, two infants (both younger than one year of age) and 13 juveniles between 11 and 19 years were the only non-adults in the sample. The highest number of individuals was observed to be between 20 and 34 years of age (n = 52). Twenty-five individuals were estimated to have been 35–49 years of age and only four were determined to have been older than 50 years of age at the time of death. Due to the fragmentary condition of some of the remains, eight individuals could only be described as

being adult and two were of unknown age (see Table 5.1). The majority of the skeletons demonstrated excellent preservation.

All bones were visually assessed for any macroscopic indication of pathological alterations, especially those associated with scurvy. Attention was given to signs of ossified haematomas (characterised by localised, well-demarcated lesions of bone apposition) (see Figure 5.1), periodontal disease (see Figure 5.2) and general widespread

Table 5.1 Age and sex distribution of individuals excavated next to the fenced Gladstone cemetery.

	J	YA	MA	OA	A	U	Total	%
Age in years	0-19	20-34	35-49	>50	>20			
Male	10	46	21	2	7	0	86	80.4
Female	3	6	4	2	0	0	15	14.0
U	3	0	0	0	1	2	6	5.6
Total	16	52	25	4	8	2	107	
%	14.9	48.6	23.4	3.7	7.5	1.9		

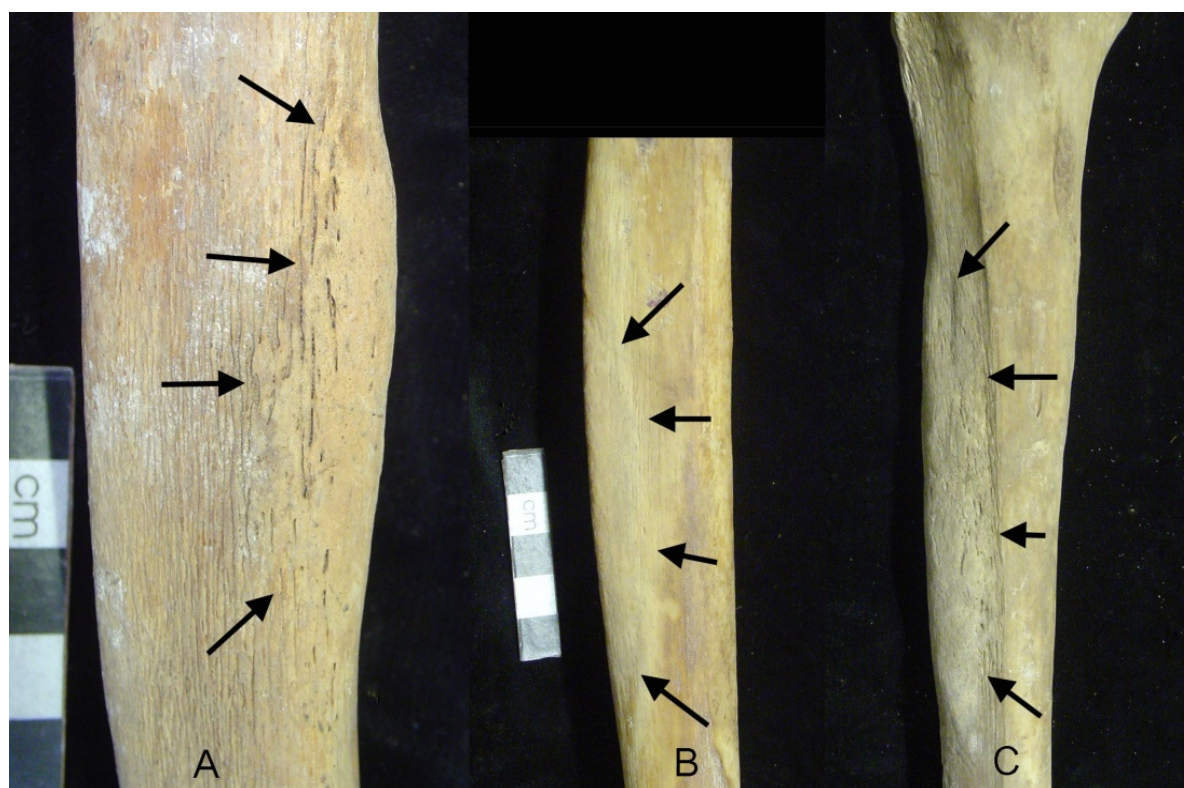J=Juveniles, YA=Young adult, MA=Middle adult, OA=Old adult, A=Adult, U=Unknown

Figure 5.1 Clearly demarcated lesions of new bone apposition (as indicated by arrows) on anterior tibiae of three individuals as a possible result of scurvy (A: GLD SE7.5, B: GLD N38.5, C: GLD N74.9).

bilateral subperiosteal bone apposition (see Figure 5.3). Diagnoses of possible scurvy were made based on the bony characteristics of the defects as well as on the distribution of the lesions across the skeleton. All lesions were compared to standard palaeopathological texts and photographs as can be found in Steinbock (1976), Maat (1984; 2004), Roberts and Manchester (1995), Mann and Murphy (1990), Larsen (1997), Aufderheide and Rodríguez-Martín (1998) and Ortner (2003).

Because other diseases such as treponemal infections were also present in this sample population, bone samples were taken from ambiguous lesions in order to perform histological investigation to increase the accuracy of diagnoses (Van der Merwe *et al.*, 2010).
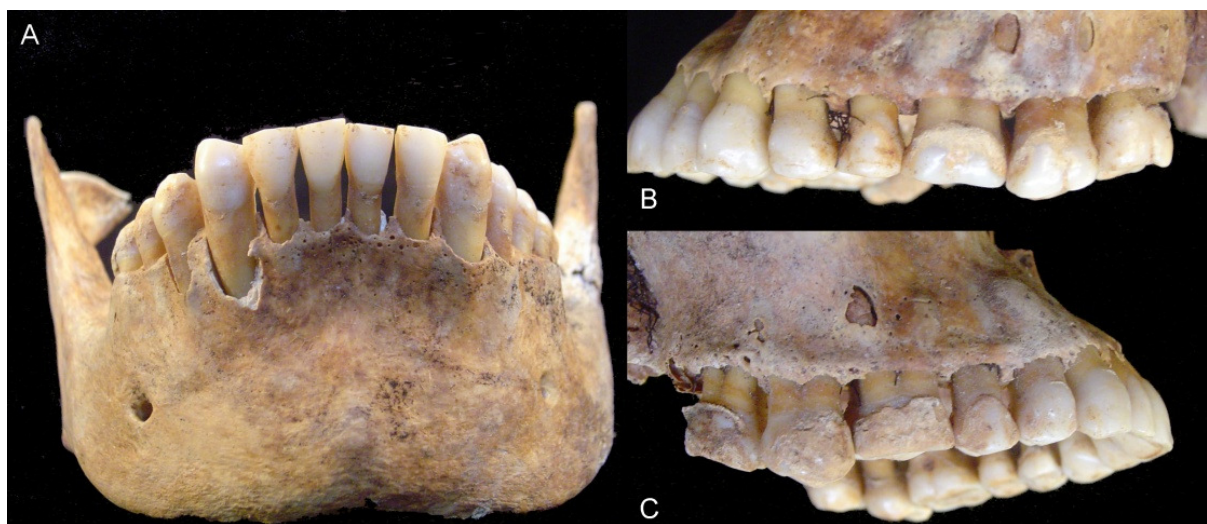

Figure 5.2 Widespread periodontal disease can be seen as observed in individual GLD S2.4, who was suggested to have suffered from scurvy. A) mandibular teeth, B) left maxilla, C) right maxilla.

5.3 Results

Possible scurvy was diagnosed in 16 individuals (14.9%), comprising 13 males (15.1%) and three females (20%) (see Table 5.2). There was no significant difference in the prevalence of scurvy between males and females ($\chi^2 = 0.22$, p-value > 0.2).

All individuals presenting with lesions were younger than 45 years of age, including one juvenile, seven young adults and eight middle aged adults. No significant differences were observed in the distribution of healed scurvy lesions between the various age groups. Scurvy was identified by the presence of mostly bilateral ossified haematomas on the tibiae (see Figure 5.1), widespead subperiosteal bone growth (most likely also associated with

slight subperiosteal bleeding) (see Figure 5.3) and periodontal disease. Although all the abovementioned pathological lesions can be indicative of other diseases when viewed separately, the combination of these lesions in one individual was interpreted as possible scurvy. A summary of the lesions observed in each individual can be seen in Table 5.2.

For example, individual GLD N31.E.1 presented with bilateral striations and patches of porous new bone formation on the anterior tibiae. Indications of periodontal disease were also observed on the maxilla and mandible. These lesions, in the absence of any signs of trauma and in conjunction with the historical records, suggested that scurvy may be a plausible explanation.

The same pattern of striated bone surfaces with widespread lesions of subperiosteal bone apposition in association with periodontal disease was noted in individuals GLD S2.1, GLD S2.9 and GLD N31.E.4. In individuals GLD S2.1 and GLD N31.E.4, subperiosteal lesions were only present on the left tibia.

Possible lesions suggestive of ossified haematomas were noted in 11 individuals (Table 5.2). The lesions were localised with clear borders, separating them from the original underlying bone (see Figures 5.1 and 5.4). All affected individuals had widespread periosteal lesions indicative of slight subperiosteal bleeding. Apart from the ossified haematomas and periosteal lesions on the tibiae, skeletons GLD SE7.6, GLD SE7.5 and GLD SE7.9 also presented with indications of periodontal disease.

Samples taken from lesions suggestive of ossified haematomas presented with an undisturbed original periosteal surface (distinctly visible on cross section) and appositional bone on top of the original periosteal surface (see Figure 5.5a). Histological investigations showed cortical bone unaffected by pathology with uninterrupted subperiosteal circumferential lamellae, indicating the level of the original periosteal surface and appositional bone (radiating outwards) on top of it (see Figure 5.5b) (Van der Merwe *et al.*, 2010). It was clear from these histological sections that the lesions were the result of ossified haematomas and not of an infective condition, since the original underlying periosteal surface of the cortical bone was not affected. In addition, no lytic changes or unstructured bone replacements, characteristic of infectious inflammation, were noted.

Table 5.2 Prevalence of skeletal lesions in individuals with possible scurvy in the Gladstone population

Case no	Sex	Age	Widespread subperiosteal bone deposition and striations	Ossified haematomas	Periodontal disease
GLDN31.E.1	M	MA	P (bilaterally on tibiae)	A	P
GLD N74.8	M	J	P (L tibia)	A	A
GLD N74.9	M	YA	P (bilaterally on tibiae)	P (ant. tibiae)	A
GLDN31.E.4	M	MA	P (ant. L femur & tibia)	A	P
GLD N34.13	M	YA	P (bilaterally on tibiae)	P (ant. R tibia)	A
GLD N38.5	M	YA	P (L tibia)	P (ant. L tibia)	A
GLD N8.5	M	YA	P (bilaterally on tibiae & R ulna)	P (ant. tibiae)	A
GLD N8.10	M	YA	P (bilaterally on femora, tibiae & fibulae)	P (ant. tibiae)	A
GLD S2.1	M	MA	P (L tibia)	A	P
GLD S2.9	M	MA	P (bilaterally on tibiae)	A	P
GLD SE7.3	M	YA	P (bilaterally on tibiae)	P (ant. tibiae)	A
GLD SE7.6	M	YA	P (bilaterally on tibiae, fibula & R femur)	P (ant. tibiae)	P
GLD SE7.9	M	MA	P(bilaterally on tibiae)	P (ant. tibiae)	P
GLD SE7.4	F	MA	P (bilaterally on tibiae)	P (R tibia & R femur)	A
GLD SE7.5	F	MA	P (bilaterally on tibiae)	P (ant. tibiae)	P
GLD S2.4	F	MA	P (bilaterally on tibiae)	P (ant. tibiae)	A
Total			16	11	7

M = male, F = female, J = Juvenile (0 – 19 years), YA=Young adult (20 – 34 years), MA = Middle adult (35 – 49 years), A = absent, P = present, ant. = anterior, R = right, L = left

The ossified haematomas were bilateral in eight of the 11 cases presenting with these lesions (72.7%). Two individuals (20%) presented with lesions only on the right tibia and one individual (10%) had a haematoma affecting the left tibia only.

Figure 5.3 Striations and widespread subperiosteal bone deposition observed on tibiae of individuals possibly suffering from scurvy (A: GLD N8.10, B: GLD N8.10, C: GLD N8.5).

Figure 5.4 Ossified haematoma (a) with closer view of lesion as indicated by black arrow (b). White arrow indicates signs of subperiosteal bone apposition. Lesion most likely developed as result of healed scurvy in a male, 25-30 years of age (GLD SE7.6).
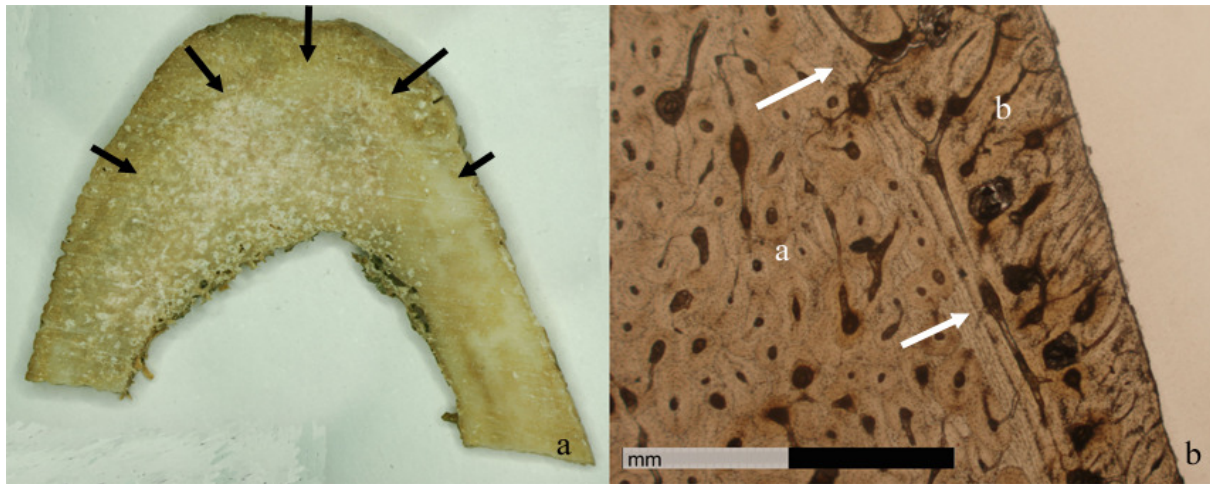
Figure 5.5 (a.) Cross section through an ossified haematoma most likely resulting from scurvy. The original periosteal surface (indicated by arrows) can be easily visualized. (b.) Histological features supporting that the observed lesions were ossified haematomas: unaffected original bone (a), original circumferential lamellae (arrows) and appositional bone (b) are clearly discernible.

5.4 Discussion

The documentation of adult scurvy is rarely seen in the description of the health status of archaeological populations. This is most likely due to the ambiguous lesions caused by this condition. Haematomas on the diaphyses of bone can also be caused by or easily mistaken for trauma, treponemal infection, non-specific osteomyelitis or an osteoblastoma, while joints with haemarthroses can be washed clean by rain and ground water movement.

It is widely known that persons suffering from vitamin C deficiency have a tendency to bleed due to defective collagen in bone and vascular walls (Barlow, 1883; Lind, 1953; Jaffe 1972). Any mechanical or physical strain on a defective blood vessel could result in haemorrhage. In a study conducted on the Johannesburg Bantu in 1962, Seftel *et al.* (1966) noted that individuals suffering from scurvy often presented with haemorrhagic swellings of the gums as well as bleeding into the muscle of the calf or posterior thigh. Steinbock (1976) and others (van Wersch, 1954; Maat, 2004) also state that pathological features are common along the adult diaphyses, rather than in the metaphyses as seen in infantile scurvy. It can also be expected that skeletal sites that receive regular minor trauma, such as the shin, will be more prone to the development of haematomas due to the increased susceptibility of the scorbutic individual to haemorrhage (Stuart-Macadam, 1989). Although very little literature is available on the presence of haematoma formation on the surface of the anterior tibia in adults due to scurvy (e.g. Aschoff & Koch, 1919; Van Wersch, 1954), it is proposed that the skeletal lesions of ossified haematomas observed in

the Gladstone remains most probably developed due to vitamin C deficiency. It is possible, however, that these lesions could have been exacerbated by trauma to the shins of these individuals.

The prevalence of scurvy within the Gladstone population (14.9%) correlates well with the documented prevalence of this disease among black individuals being treated at the Kimberley Hospital. In 1897, 311 patients (16.7% of all admissions) were being treated for scurvy. According to the report, this could have been prevented if ''employers [were] properly feeding their men'' (CGHVPP, 1899). It was also stated that due to the neglect by the employers, it became the hospital's responsibility to cure the malnourished 'Natives' employed in the mines. During the last six weeks of 1899, up to 292 patients (17.8% of all admissions) were being treated for scurvy, of which 52 died (Medical Officer of Health, 1900).

A high prevalence of scurvy can be expected in groups following a diet consisting mainly of maize meal and occasional coarse meat, which was the only food supplied by the employers and compounds. There were even times when no food was being supplied to compound workers and they were responsible for buying and preparing their own meals (Harries, 1994). Therefore, these diets were normally high in carbohydrates, low in animal proteins and low in fresh fruit and vegetables (Grusin & Samuel, 1957; Seftel *et al.*, 1966). When considering the lack of fresh fruit and vegetables, Kimberley's climate should be kept in mind. Nineteenth century Kimberley, as is still the case, was very hot and dry, plagued by fires and brutal dust storms (McNish, 1970; Roberts, 1976). Accordingly, naturally growing fruit and vegetables were scarce and agricultural enterprises difficult.

Another possible explanation for the high prevalence of scorbutic individuals found in this population can be the regular consumption of homemade traditional beer and alcohol (McNish, 1970). The regular consumption of beer stored in iron and/or tin cans may cause the consumer to develop siderosis which, through the oxidation of serum vitamin C, may lead to the development of scurvy (Seftel *et al.*, 1966). Historical documents indicate that alcoholic beverages were consumed in large quantities by the labourers in Kimberley (Harries, 1994). Sorghum beer was also prepared in large quantities and together with European liquors, became the ''cultural markers, binding black workers together'' (McNish, 1970; Harries, 1994:58). This habit of overindulging, which mainly occurred on weekends, resulted in a ''large absentee rate on Mondays, when as many as 50% of the men failed to report for work'' (Harries, 1994:58).

Healed scurvy was diagnosed in the Kimberley population sample based on the presence of periodontal disease, ossified haematomas (especially on the anterior tibiae) and widespread patches of subperiosteal bone deposition. It is important to consider that although gingivitis is one of the characteristic clinical symptoms of scurvy, it is very inconsistent (Fain, 2005). It has been suggested that hypertrophy and bleeding of the gingivae mostly occurs in patients with teeth, and that the inflammation is more severe in those with poor dental hygiene (Fain, 2005). Thus, although scurvy and the resulting gingivitis can be responsible for the bone changes indicative of periodontal disease observed in the investigated skeletal remains, it should also be considered that several other factors influence the development of periodontal disease, including the age of the individual, the presence of plaque micro-organisms, hereditary factors, the availability of dental care and the plaque-encouraging characteristics of the person's daily diet (Hillson, 1998). Thus, although the presence of periodontal disease in association with the widespread subperiosteal bone apposition and localised ossified haematomas support the possibility of scurvy, the absence of periodontal disease, or its presence without the associated skeletal lesions, is most likely not indicative of the condition.

The differential diagnosis for lesions observed on the anterior tibiae in this sample population includes trauma resulting in heamatoma formation and later ossification thereof, saber shin tibiae as a result of treponematosis, non-specific osteomyelitis and possible osteoblastomas. In order to exclude the possibility that these lesions may be the result of treponematosis, non-specific osteomyelitis or osteoblastomas, histological investigations were also carried out on the majority of the lesions (Van der Merwe *et al.*, 2010).

Histological investigations confirmed the presence of ossified haematomas and showed that the appositional bone did not develop due to infective bone changes. The appositional bone also did not have the dense woven bone trabecular structure as would be expected for an osteoblastoma (Vigorita, 1999; Ortner, 2003). All histological sections were characterised by a clearly visible original periosteal surface (distinctly visible on cross-section) and appositional bone on top of the original periosteal surface. The cortical bone was unaffected by pathology, with circumferential lamellae indicating the level of the original periosteal surface and appositional bone (radiating outwards) on top of the external circumferential lamellae (Van der Merwe *et al.,* 2010). Accordingly, it was confirmed by the histological sections that these lesions were indeed the result of ossified haematomas.

Trauma must be considered in the differential diagnosis for the ossified haematomas on the anterior tibiae. Considering that these individuals were most probably all working in the mines and many consumed large amounts of alcohol, accidents and skirmishes would have often occurred. It is also well known that ossified haematomas, as a result of scurvy, will only develop once the patient has recovered from the scorbutic state (Murray & Kodicek, 1949). Therefore, it can be argued that the individuals in the Kimberley sample population had to have sufficient amounts of vitamin C in their diet at certain times, otherwise ossification of the haematomas would not have occurred. Several episodes of vitamin C deficiency, probably alternated with treatment in the local hospitals or return of migrant labourers to a more variable diet when they returned home, as well as repeated minor or more major traumatic incidents to the anterior tibiae; all most likely contributed to the patterns of pathological changes seen in this population. The distribution of the lesions supports scurvy as a more likely cause of the haematomas when compared to trauma since lesions were most often symmetrical, affecting both the left and right anterior tibiae, whereas in the cases where the upper limbs were also affected it was usually only unilaterally. This distribution of lesions is very similar to the distribution of lesions described by Maat (2004) in the whalers and can most likely be associated with the strain on these bones due to weight bearing. It would be expected that haematomas as a result of trauma, whether accidental or violent, would be more widespread, much less symmetrical and there would be less similarities in the distribution of the lesions among those exhibiting them.

Therefore, it can be concluded that lesions suggestive of adult healed scurvy were observed in 16 individuals from the Gladstone skeletal sample. These lesions included ossified haematomas (often bilateral), widespread subperiosteal bone apposition and periodontal disease. Histological investigations confirmed the nature of the ossified haematomas in those that were sampled and investigated microscopically (Van der Merwe *et al.,* 2010). Hospital records and historical documents describing the prevalence of scurvy in the Kimberley and Compound Hospitals and the daily diet of the black mine workers supported these findings. Therefore, this study provides one of the few descriptions of skeletal lesions caused by scurvy in adult individuals. Histological analysis of possible ossified haematomas helped to confirm the diagnoses, and should be included in such an investigation whenever possible.

References

Asala, S.A. 2001. Sex determination from the head of the femur of South African whites and blacks. *Forensic Science International* 117: 5–22.

Aschoff, L. and Koch, W. 1919. Skorbut, eine pathologischanatomische studie. Gustav Fisher Verlag: Jena.

Aufderheide, A.C. and Rodríguez-Martín, C. 1998. *The Cambridge Encyclopedia of human paleopathology*. Cambridge: Cambridge University Press.

Barlow, T. 1883. On cases described as 'acute rickets' which are probably a combination of scurvy and rickets, the scurvy being essential, and the rickets a variable, element. *Medico-Chirurgical Transactions* 66:159–219.

Brickley, M. and Ives, R. 2006. Skeletal manifestations of infantile scurvy. *American Journal of Physical Anthropology* 120:163–172.

Cape of Good Hope Votes and Proceedings of Parliament. 1899. Hospitals and Asylums Report for 1898 Appendix I.

De Luna, R.H., Judson Colley, B., Smith, K., Divers, S.G., Rinehart, J. and Marques, M.B. 2003. Scurvy: an often forgotten cause of bleeding. *American Journal of Hematology* 73:85–8587.

De Villiers, H. 1968. Sexual dimorphism of the skull of the South African Bantu-speaking Negro. *South African Journal of Science* 84:118–124.

Fain, O. 2005. Musculoskeletal manifestations of scurvy. *Joint Bone Spine* 72:124–128.

Franklin, D., Freedman, L. and Milne, N. 2005. Sexual dimorphism and discriminant function sexing in indigenous South African crania. *Homo* 55: 213–228.

Grusin, H. and Samuel, E. 1957. A syndrome of osteoporosis in Africans and its relationship to scurvy. *Journal of Clinical Nutrition* 5:644–650.

Hamilton, W. and Dyke, M.B. 1918. Outbreak of scurvy in the South African native labour corps. *Lancet* Oct: 513–515.

Harries, P. 1994. *Work, Culture and Identity. Migrant Laborers in Mozambique and South Africa, c 1860–1910*. Johannesburg: Witwatersrand University Press.

Hillson, S. 1998. *Dental Anthropology*. Cambridge: Cambridge University Press.

Hirschmann, J.V. and Raugi, G.J. 1999. Adult scurvy. *Journal of the American Academy of Dermatology* 41:895–906.

Jaffe, H.L. 1972. *Metabolic, Degenerative and Inflammatory Diseases of Bones and Joints*. Philadelphia: Lea and Febiger.

Jochelson, K. 2001. *The Colour of Diseases, Syphilis and Racism in South Africa 1880–1950*. New York: Palgrave.

Krogman, W.M. and İşcan, M.Y. 1986. *The Human Skeleton in Forensic Medicine*, 2nd ed. Springfield: Charles C Thomas.

Larsen, C.S. 1997. *Bioarchaeology. Interpreting Behavior from the Human Skeleton*. Cambridge: Cambridge University Press.

Leary, J.G. 1891. Divisions of Kimberley. In: *Blue Book on Native Affairs G4*. Cape of Good Hope. Ministerial Department of Native Affairs. Cape Town: WA Richards & Sons.

Lind, J. 1953. *Lind's Treatise on Scurvy*. Stewart CP, Guthrie D (eds). Edinburgh: University Press.

Maat, G.J.R. 1984. Scurvy in Dutch whalers buried at Spitsbergen. In: *Proceedings of the Palaeopathology Association 4th European Meeting*, Haneveld GT, Perizonius WRK, Janssens PJ (eds). Paleopathology Association, Utrecht; pp. 140–148.

Maat, G.J.R. 2002. History and pathology of a disregarded disease. *Histopathology* 41: 460–462.

Maat, G.J.R. 2004. Scurvy in adults and youngsters: The Dutch experience. A review of the history and pathology of a disregarded disease. *International Journal of Osteoarchaeology* 14: 77–81.

Maat, G.J.R. and Uytterschaut, H.T. 1987. Microscopic observations on scurvy in Dutch whalers buried at Spitsbergen. In: *Proceedings of the Palaeopathology Association 5th European Meeting*. Capecchi V, Rabino Massa E (eds). Paleopathology Association, Sienna; pp. 211–218.

Mann, R.W. and Murphy, S.P. 1990. *Regional Atlas of Bone Disease: A guide to Pathologic and Normal Variation in the Human Skeleton*. Springfield: Charles C Thomas.

McNish, J.T. 1970. *The Glittering Road*. Cape Town: C. Struik.

Medical Officer of Health. 1900. *Medical Officer of Health reports for 1899 and 1900*. Unpublished report held in Kimberley Africana Library, Kimberley.

Murray, P.D.F. and Kodicek, E. 1949. Bones, muscles and vitamin C. III. Repair of the effect of total deprivation of Vitamin C at the proximal ends of the tibia and fibula in guinea-pigs. *Journal of Anatomy* 83:285–295.

Oettlé, C. and Steyn, M. 2000. Age estimation from sternal ends of ribs by phase analysis in South African blacks. *Journal of Forensic Sciences* 45:1071–1079.

Ortner, D.J. 2003. *Identification of Pathological Conditions in Human Skeletal Remains*, 2 ed. Amsterdam: Academic Press.

Ortner, D.J. and Ericksen, M.F. 1997. Bone changes in the human skull probably resulting from scurvy in infancy and childhood. *International Journal of Osteoarchaeology* 7:212–220.

Pangan, A.L. and Robinson, D. 2001. Hemarthrosis as initial presentation of scurvy. *Journal of Rheumatology* 23:1923–1925.

Petit, J.L. 1741. Traite des maladies os I, II. Paris.

Reuler JB, Broudy V, Cooney T. 1985. Adult scurvy. *Journal of the American Medical Association* 253:805–807.

Roberts, B. 1976. *Kimberley Tubulent City*. Cape Town: Pioneer Press

Roberts, C. and Manchester, K. 1995. The Archaeology of Disease, 2 ed. Stroud: Alan Sutton Publishing.

Seftel, H.C., Malkin, C., Schmaman, A., Abrahams, C., Lynch, S.R., Charlton, R.W. and Bothwell, T.H. 1966. Osteoporosis, scurvy and siderosis in Johannesburg Bantu. *British Medical Journal* 1:642–646.

Steinbock, R.T. 1976. *Paleopathological Diagnosis and Interpretation*. Springfield: Charles C. Thomas.

Stoney, W.W. 1900. *Report of the Medical Officer of Health, Kimberley, for the years 1898*. Unpublished report held in Kimberley Africana Library, Kimberley.

Stuart-Macadam, P. 1989. Nutritional deficiency diseases: a survey of scurvy, rickets and iron deficiency anemia. In: *Reconstruction of Life from the Skeleton.*, İşcan, M.Y. and Kennedy, K.A.R. (eds). New York: Alan R. Liss.

Van der Merwe, A.E. 2007. *Human skeletal remains from Kimberley: an assessment of health in a 19th century mining community*. Unpublished MSc. thesis, University of Pretoria.

Van der Merwe, A.E., Maat, G.J.R. and Steyn, M. 2010. Ossified haematomas and infectious bone changes on the anterior tibia: histomorphological features as an aid for accurate diagnosis. *International Journal of Osteoarchaeology*. 20(2):227-239.

Van Wersch H.J. 1954. *Scurvy as a Skeletal Disease. A Comparative Study of Scurvy and Rickets, Clinically, Histologically, Histochemically, Biochemically and Roetgenologically.* Utrecht: Dekker & van de Vegt

Vigorita, V.J. 1999. *Orthopaedic Pathology*. Philadelphia: Lippincott Williams & Wilkins