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

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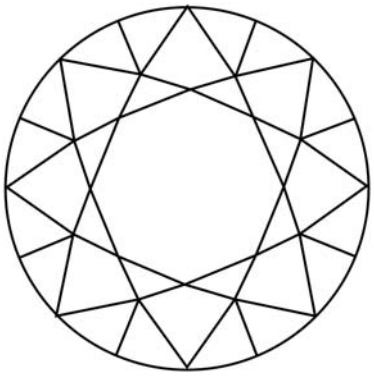

CHAPTER 6

Ossified Haematomas and Infectious Bone Changes on the Anterior Tibia: Histomorphological Features as an Aid for Accurate Diagnosis

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Ossified haematomas and infectious bone changes on the anterior tibia: histomorphological features as an aid for accurate diagnosis

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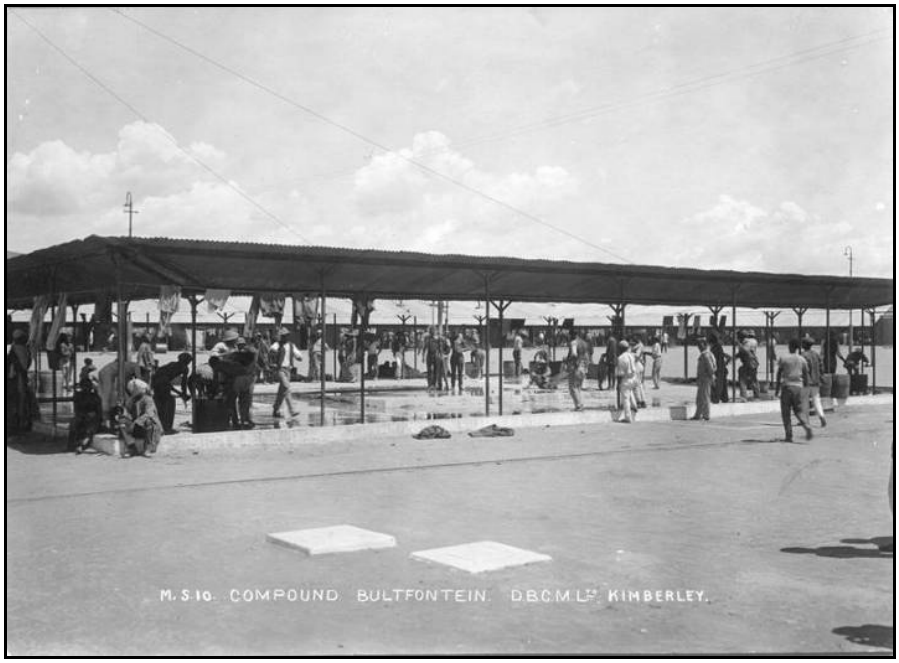
Kimberley Town Hall, 1902
(McGregor Museum Kimberley Photography nr.5305)



Bultfontein Compound, 1900s
(McGregor Museum Kimberley Photography nr.5341)

Abstract

Examination of the histological structure of bone not only helps investigators to estimate age at death, but can also aid in the diagnosis of palaeopathological lesions. The purpose of this paper is to assess whether histological features, as described in the literature, can confirm the macroscopic diagnoses of ossified subperiosteal haematomas, associated with healed scurvy, and syphilitic bone changes observed on the anterior tibiae of individuals from a 19th century mining community from Kimberley, South Africa.

The frequent occurrence of these two diseases amongst the deceased was well established in related hospital and governmental documents. A section of bone was removed from lesions on the tibiae of 14 individuals. These bone changes were macroscopically diagnosed as being indicative of either treponematosis, ossified subperiosteal haematomas, or non-specific periostitis. Cross-sections were prepared for microscopic investigation, using a manual ground section technique.

Ossified haematomas were histologically identified in seven individuals. These sections were characterised by normal cortical bone, an intact original periosteal surface, and newly formed, radiating trabecular bone apposing it. Three phases of ossified subperiosteal haematoma formation and remodelling could be distinguished. Infectious bone changes, most likely associated with treponematosis, were observed in one individual. These were histologically characterised by lysis and numerous resorption holes/channels. No clear distinction could be made between the internal spongy, cortical or newly formed bone. Histological features described by some authors as characteristic of this condition could not be identified. In addition, three individuals presented with microscopic features indicative of both the aforementioned bone affections, and three did not show any pathological changes on microscopic level.

It was concluded that although specific pathological conditions can most likely not be diagnosed purely on the basis of histomorphological observations, broad distinctions could be made between lesions caused by the ossification of subperiosteal haematomas and bone changes due to infectious diseases.

6.1 Introduction

Examination of the histological structure of archaeological bone not only helps investigators to estimate the age at death of individuals, informs them whether the bone is human or not, and gives information regarding the preservation of the bone, but can also aid in the accurate diagnosis of pathology (Martin & Armelagos, 1979; Garland, 1993; Herrmann, 1993; Schultz, 2001; Maat, 2004). Reliable diagnosis of pathological bone lesions is the basis for the reconstruction of diseases in past populations. Macroscopic investigations, conventional X-rays and CT scans are techniques available to study pathological lesions present in bone, but false diagnoses are still common due to the absence of soft tissue evidence and similarities in the formation of bone lesions in different diseases (Ortner & Putschar, 1981; Mann & Murphy, 1990; Schultz, 2001). Therefore, it is important that different techniques, microscopic methods in particular, should be developed and refined in order to increase the accuracy with which the diagnosis of pathological lesions can be made.

For the purposes of this study, microscopic features of proliferative reactions on long bones will be reviewed briefly, in particular lesions on the tibiae caused by healed scurvy and treponemal infection. Numerous diseases can be responsible for bone formation on the surface of long bones, such as non-specific periostitis, non-specific osteomyelitis, treponemal disease, leprosy, healed scurvy and mechanical trauma, to name a few. Two lines of bone behaviour can be recognised during microscopic investigation of bone, namely proliferative (osteoblastic) or lytic (osteoclastic) patterns (Cotran *et al.*, 1999; Vigorita, 1999). The first is responsible for the deposition of new bone, and the latter causes the resorption of bone (Coetzee *et al.*, 2003; Junqueira & Carneiro, 2003; Ross & Pawlina, 2006).

According to Schultz (2001), three groups of bone changes due to newly formed bone can be described microscopically (i.e., proliferative patterns): haemorrhagic, inflammatory, and tumorous. Only the first two will be discussed further. Haemorrhagic changes, such as ossified subperiosteal haematomas, are characterised by newly-built spongy bone on the intact external surface of the original bone (Maat & Uytterschaut, 1987; Schultz, 2001, 2003; Maat, 2004). It has been shown that such changes may occur in cases of healed scurvy after a vitamin C-deficient period. Experimental histological investigation of diaphyseal bone in vitamin C deficient guinea pigs indicated that the ossified haematomas

consisted of narrow bony trabeculae radiating from the original bone surface to the periosteum (Murray & Kodicek, 1949). As was also noted by Schultz (2001), these radiating trabeculae often join together with bony bridges. At the site of the ossified haematoma the external circumferential lamellae of the original bone are still intact and the underlying compact bone substance seems unaffected. It was also shown in guinea pigs that once the vitamin C-deficient diet is corrected, the structure of the radiating trabeculae starts to change: spaces separating the trabeculae begin to narrow and the trabecular bone gradually gets remodelled into compact bone, while still retaining its former radiating architectural characteristics (Murray & Kodicek, 1949). Therefore, in the long term, the radiating structure of the previously formed trabeculae may still stay visible.

Inflammatory diseases due to infection, such as non-specific periostitis, non-specific osteomyelitis and treponematosis, can also cause bone apposition on the external surface of long bones. In these cases, however, the border between the original bony cortex and the newly formed bone, namely the periosteal surface, breaks up and disappears (Vigorita, 1999; Maat, 2004).

According to Schultz and others, lesions caused by treponemal disease are also characterised by 'polsters' and 'grenzstreifen' when examined under polarised light (Schultz, 2001, 2003; Von Hunnius *et al.*, 2006). 'Polsters'can be identified as lamellar outgrowths at the periosteal level resembling pillows separated from each other by blood vessels. These structures seem regular, repetitive and positioned side-by-side. According to the same authors, 'polsters' may also be observed in bony lesions caused by leprosy, but then they are said to often be underdeveloped and flat. 'Grenzstreifen', also translated as 'border stripes', can be identified as a fine, narrow, band-like structure that marks the remaining original periosteal surface of the bone. On the external aspect of the 'grenzstreifen', newly formed bone will then be visible as a solid mass. Another important characteristic of infectious changes in bone, in particular treponemal disease, is said to be the osteoclastic changes of the endosteal bone and bony trabeculae. This process results in lysis, i.e. resorption holes/canals, corroded structures and vestiges of extensive remodeling visible throughout the thickness of the original cortical bone (Schultz, 2001, 2003; Von Hunnius *et al.*, 2006).

The purpose of this paper is to assess whether histological features, as described by Murray and Kodicek (1949), Maat and Uytterschaut (1987), Maat (2004), Schultz (2001, 2003) and Von Hunnius *et al.* (2006), correlate with the macroscopic diagnoses of ossified

haematomas (most probably resulting from healed scurvy) and syphilitic bone changes observed on the anterior tibiae of individuals from a 19th century mining community from Kimberley, South Africa. The frequent occurrence of these two diseases amongst the deceased was well-established in related hospital and other government sources (CGHVPP, 1899; Medical Officer of Health, 1900).

6.2 Materials and Methods

In April 2003, the Sol Plaatjie Municipality (Kimberley, South Africa) unknowingly disturbed several unmarked graves outside the fenced Gladstone cemetery, while digging a storm-water trench. The disturbed remains were most likely those of diamond miners who had died between 1897 and 1900 in the Kimberley and surrounding hospitals. They had been given paupers' burials. The McGregor Museum in Kimberley became involved through the South African Heritage Resources Agency (SAHRA), who requested them to investigate the graves. Consequently, all graves disturbed by the ground-moving machinery were exhumed. Preservation of the remains was found to be remarkably good in most cases.

Sex determination and estimation of age at death was done for each skeleton using standard anthroposcopic techniques such as the width of the subpubic angle, femoral head diameter, width of the sciatic notch, sternal ends of the ribs, the degree of cranial suture closure, tooth eruption and changes to the face of the pubic symphysis (e.g. De Villiers, 1968; Krogman & Íşcan, 1986; Hillson, 1998; Oettlé & Steyn, 2000; Asala, 2001; Franklin *et al.*, 2005). A total of 107 skeletons were exhumed from the trench which included 86 males, 15 females and 6 individuals of unknown sex. 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 present in the sample. The highest number of individuals was observed to be between 20 and 34 years of age (n=52). Twenty-five persons were estimated to have been 35 to 49 years old at the time of death. Only four individuals were found to have been older than 50 years. Due to the fragmentary condition of 10 skeletons, eight individuals could only be described as being adult, and the age of two other persons stayed undetermined (Van der Merwe & Steyn, 2006; Van der Merwe, 2007).

Diagnoses of pathological lesions on a macroscopic level were done using standard palaeopathological texts and pictures such as can be found in Steinbock (1976), Roberts

and Manchester (1995), Mann and Murphy (1990), Aufderheide and Rodríguez-Martín (1998) and Ortner (2003). Macroscopically, pathological lesions indicative of non-specific osteomyelitis, treponemal disease, tuberculosis, scurvy, amputations, fractures and some congenital abnormalities were found, amongst others (Van der Merwe & Steyn, 2006; Van der Merwe, 2007).

Indeed, historical documents supported the presence of many macroscopically observed pathological conditions within this population. For instance, it was reported that in 1897 a total of 311 individuals were admitted to Kimberley Hospital with manifest scurvy. Also, a high prevalence of diseases such as pneumonia, treponematosis, tuberculosis, as well as cases of trauma, were well documented in hospital reports and governmental documents (CGHVPPt, 1898; Stoney, 1900).

After anthropological investigations commenced, it became evident that it would be of great advantage to sample re-occurring pathological lesions on the anterior tibiae in order to increase the accuracy of diagnoses. Therefore, a 3–4mm transverse section of bone was removed from lesions on the anterior tibia of 14 individuals. Based on macroscopic investigations, these lesions had initially been diagnosed as ossified haematomas (see Figure 6.1), most likely associated with healed scurvy, in seven individuals (see Table 6.1). Two individuals had been diagnosed with treponemal disease (see Figure 6.2), three persons with lesions indicative of both treponemal disease and ossified haematomas, and two skeletons with lesions indicating possible non-specific periostitis (see Table 6.1).

Treponematosis was macroscopically diagnosed in individuals presenting with saber shin tibiae, gummatous osteomyelitis, diffuse periosteal and cortical bone thickening, and stellate scars on the cranial vault (Steinbock, 1976; Hackett, 1978; Reichs, 1989; Maat *et al.*, 1997; Ortner, 2003). Ossified haematomas, probably associated with healed scurvy, were macroscopically characterised by localised and well-demarcated lesions of bone apposition (Mann & Murphy, 1990; Maat, 2004). These lesions were usually symmetrical, and the majority of individuals presented with varying stages of bone reaction due to periodontal disease.

Sampling of the pathological lesions was done by making two parallel transverse cuts with a hacksaw, halfway through the bone shaft. These cuts were made perpendicular to the long axis of the bone. Care was taken not to damage the visible layer of bone growth on top of the original bone surface. By inserting a thin metal device into one of the cuts and bending it towards the second cut, the sample broke loose a the base of the two cuts

Figure 6.1 Ossified haematoma on the anterior tibia of a male, 28–34 years of age. (GLD SE7.3).

and could be removed. The section was bagged and labeled with the number of the individual, the anatomical location from where the sample was taken, as well as the initial macroscopic diagnosis of the pathology. Cross-sections were prepared for microscopic investigation, using a manual ground section technique described by Maat *et al.* (2000, 2001).

Each section was first inspected macroscopically. The form, distribution and nature of the new bone growth were documented. Next, each section was studied with both bright field and polarised light. Attention was given to the micro-architecture of the compact bone structure and external circumferential lamellae, as well as to the appositional bone in cases where it was present.

6.3 Results

Bone sections of 14 individuals were studied. Histological observations confirmed the presence of ossified haematomas in seven of these individuals (GLD N8.4, N8.5, N34.13, N38.5, S2.4, SE7.3, SE7.9), as can be seen in Table 6.1. These lesions were positioned on top of normal cortical bone, which itself was not affected by the pathological condition. During histological investigation it was found that the original periosteal surface, represented by the original external circumferential lamellae (see Figure 6.3), was intact in all of the abovementioned samples and could be followed throughout the section. In some

Figure 6.2 Humeri (A), ulnae (B), fibulae (C) and tibiae (D) of a male, 30–45 years of age (GLD N 74.7). The individual most likely suffered from treponematosis. Note the swollen appearance of the tibiae, distal fibulae, distal right humerus and distal left ulna.

cases it was interrupted in spots on the section, but still easy to visualise. The newly formed bone on the outside of the original periosteal surface was composed of radiating trabeculae (see Figure 6.4), as described by Murray and Kodicek (1949) in guinea pigs. These trabeculae were perpendicular to the periosteal surface of the bone.

Three phases of remodelling could be distinguished during the examination of the ossified subperiosteal haematomas. Recently ossified haematomas presented with very characteristic loosely arranged radiating trabeculae, as can be seen in individual GLD SE7.9 (see Figure 6.5). Here, the newly-formed bone seemed porous and many resorption

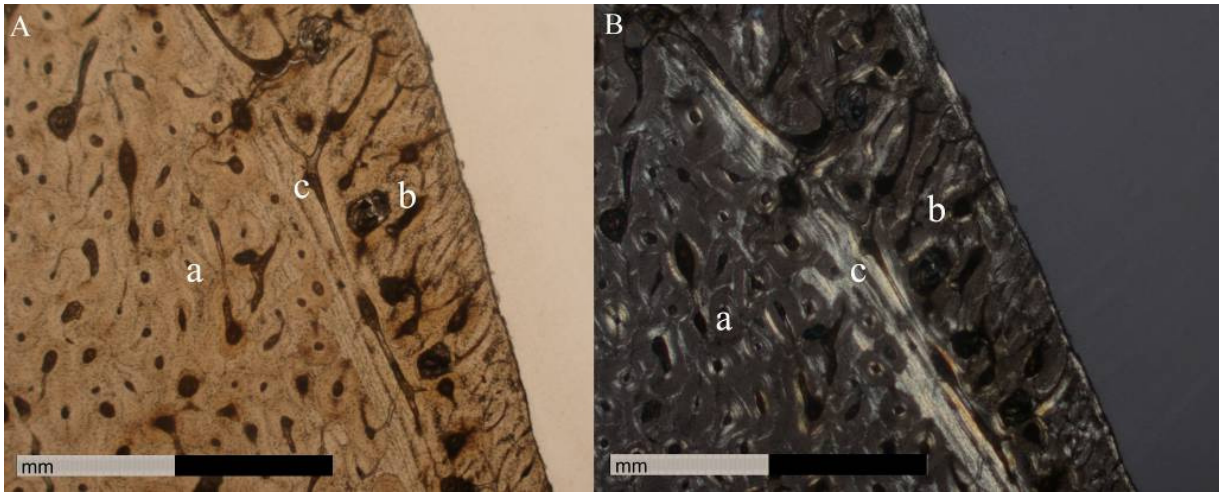


Figure 6.3 Histological structure of a bone lesion most likely caused by an ossified haematoma. Figure A shows the original cortical bone structure (a), original periosteal surface represented by original circumferential lamellae (c) and appositional bone (b) when viewed under normal bright light, and Figure B, when viewed with polarized light.

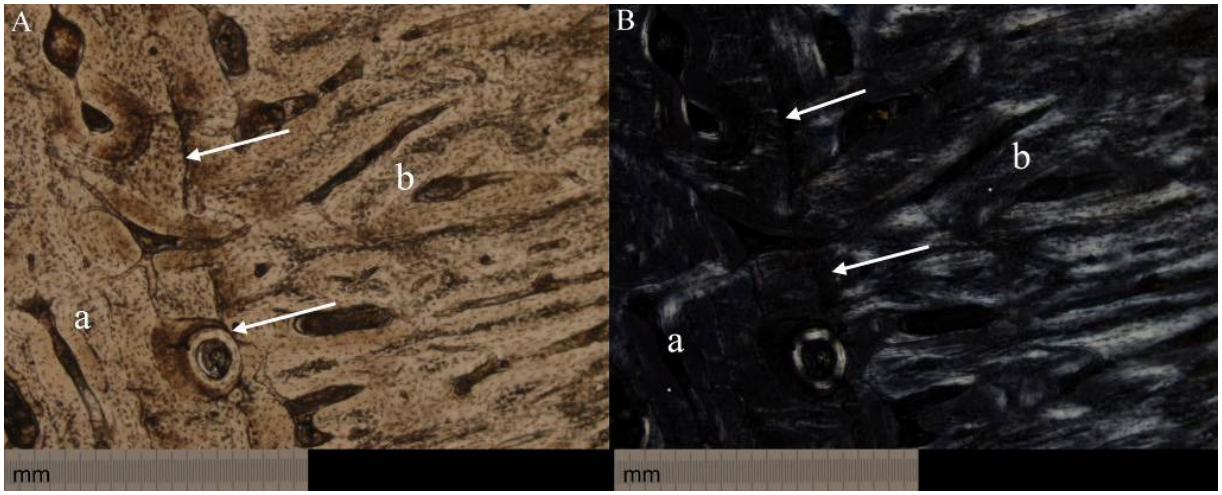


Figure 6.4 Radiating structure of appositional bone observed in an ossified haematoma. Original cortical bone (a), original periosteal surface (indicated by arrows) and appositional bone (b) can be seen here. Note the radiating structure of the appositional bone when viewed under bright light (Figure A). The structure becomes even more visible when viewed with polarized light (Figure B).

holes/canals were present. The second stage (for example in GLD SE7.3) is characterized by remodelling of the aforementioned trabeculae and filling-in of the openings between them (see Figure 6.6). Although in this case the various original trabeculae cannot be distinguished as separate anymore, the appositional bone still retains its radiating character. The last phase characterises very long-standing lesions, and can be seen in individuals GLD S1.3 and GLD N8.4. Although the appositional bone still retains its radiating structure (see Figure 6.7), bone remodeling into Haversian systems has commenced in the appositional bone, making the distinction between the ossified haematoma and the original compact

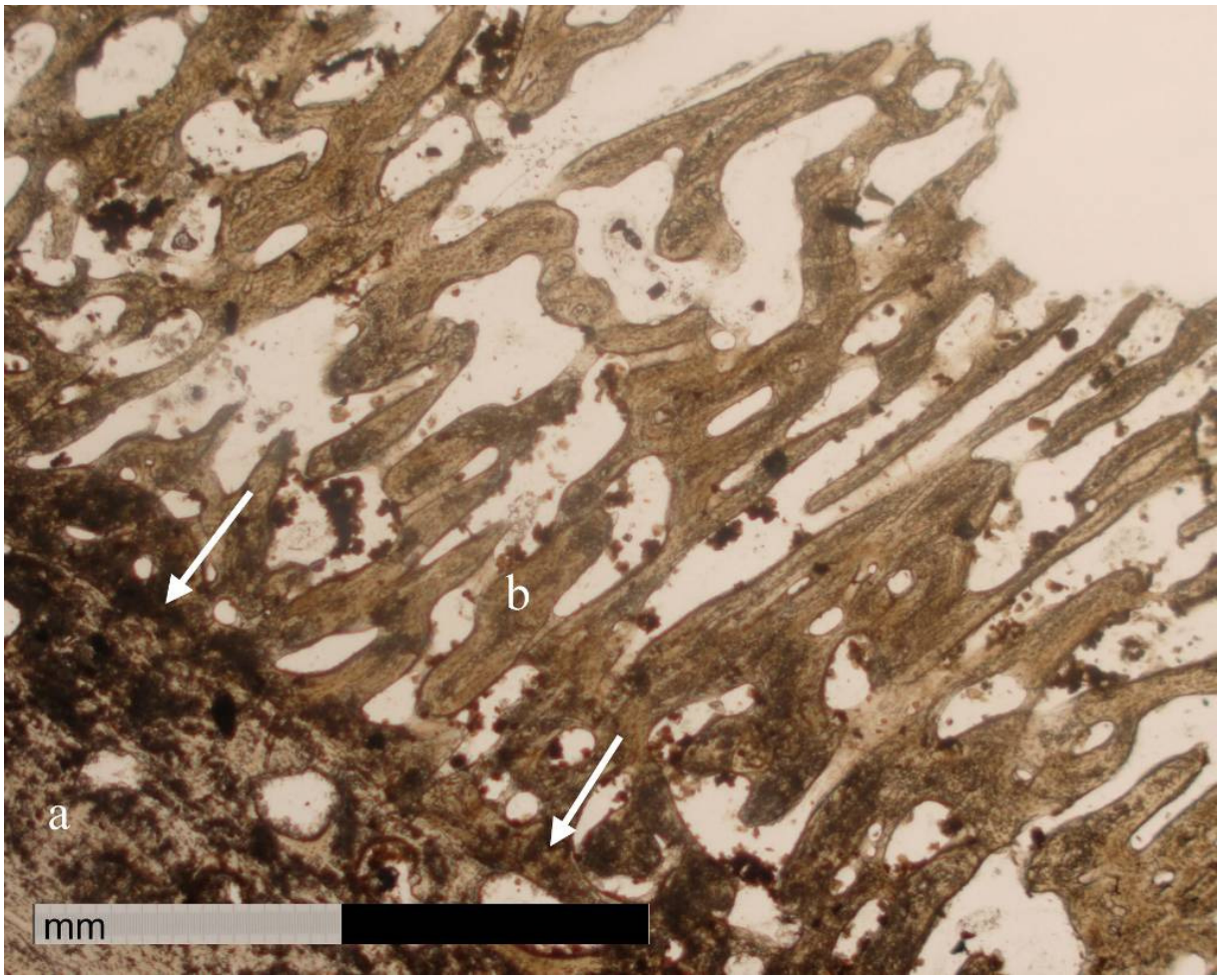


Figure 6.5 Phase I of the ossification of a subperiosteal haematoma. The unaffected original cortical bone (a), original periosteal surface (arrows) and very characteristic radiating trabeculae of the appositional bone (b) can be identified.

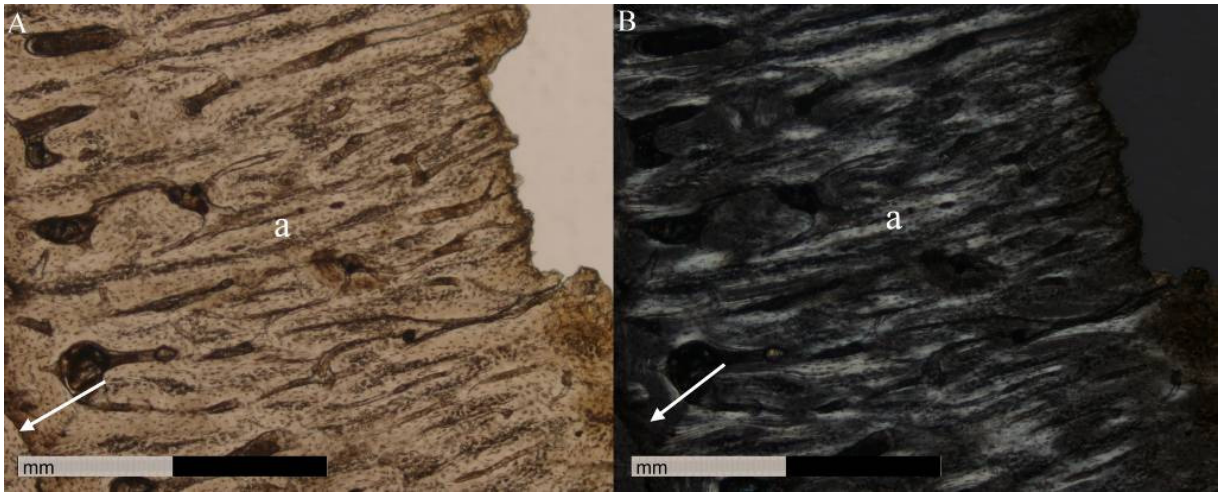


Figure 6.6 Phase II of remodelling of a subperiosteal haematoma. The original periosteal surface (arrows) and appositional bone (a) can be seen when viewed with bright (A) and polarized light (B). Note that although spaces between the original radiating trabeculae in appositional bone had been filled in, the new bone still retains a radiating structure.

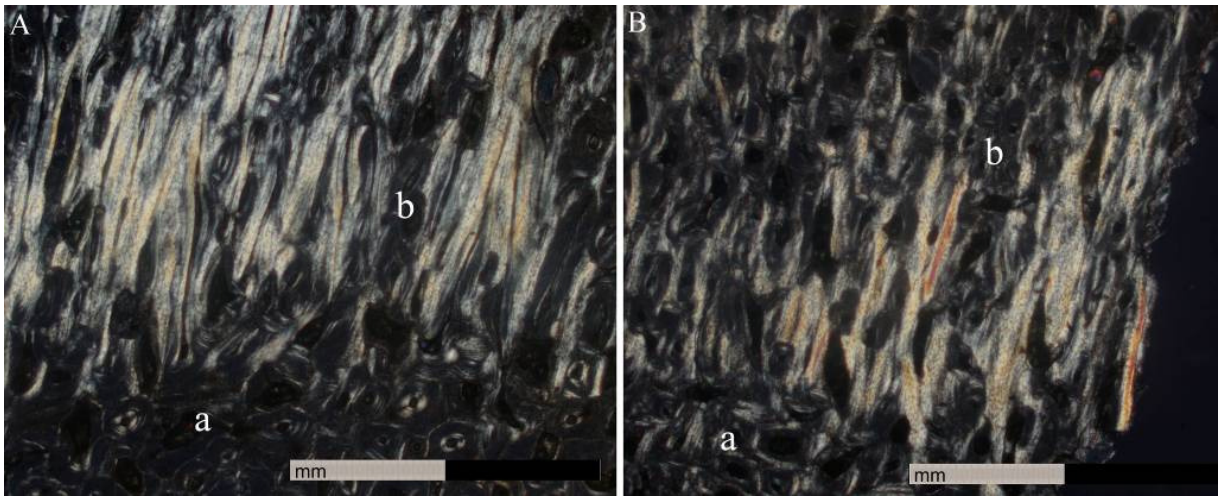


Figure 6.7 Phase III of remodelling of a subperiosteal haematoma. Long-standing ossified haematomas of GLD S1.3 (A) and GLD N8.4 (B) viewed with polarized light. Although the original cortical bone (a) and radiating structure of appositional bone (c) can still be clearly distinguished, the original periosteal surface had become vague and remodelling of appositional bone into Haversian bone, resembling cortical bone, had begun.

bone less clear. Histological features confirmed the presence of osteomyelitis in one case (see Table 1). It should be mentioned here that this term includes all infectious bone changes such as lesions caused by non-specific osteomyelitis, treponematosis, leprosy and tuberculosis. Clear and unmixed histological indications of infectious bone changes were observed in this case (GLD N74.7). The cortical bone seemed extremely thickened on cross-section (see Figure 6.8). On a histological level, intense remodeling with numerous resorption holes/canals was present (see Figure 6.9), giving the section a porous appearance and making distinction between the internal spongy bone and the cortical bone almost

impossible. No original circumferential lamellae, as were seen in the ossified haematomas, were present in this section. No separable bone apposition or radiating bone structures were visible. Histological features such as 'grenzstreifen' and 'polsters', described by Schultz (2001, 2003) as characteristic of treponematosis, could not be identified.

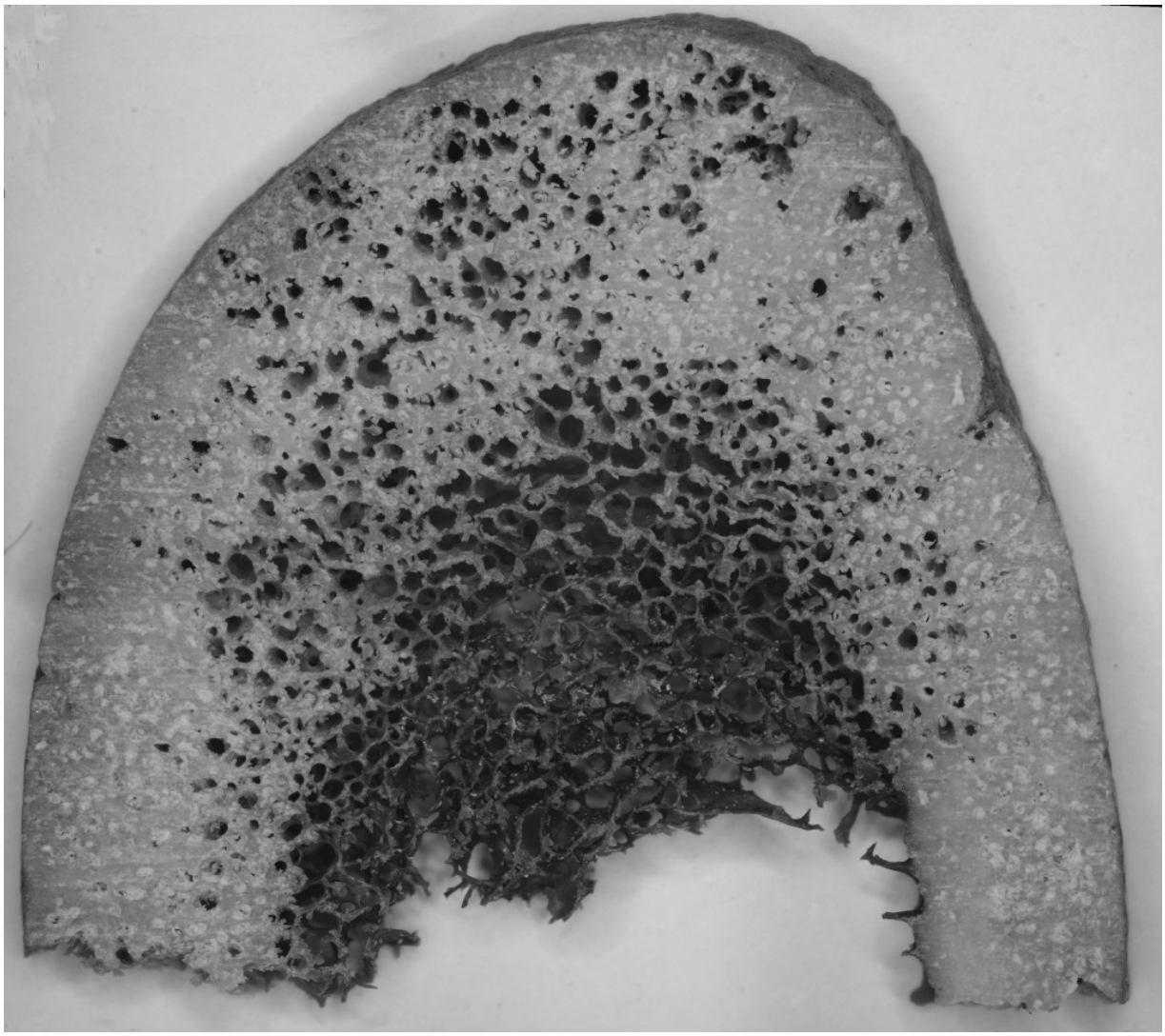


Figure 6.8 Cross section through the anterior tibia of GLDN74.7 affected by treponemal disease.

In three cases histological findings confirmed the macroscopic diagnoses but also helped to identify the presence of more than one pathological condition (NOP3/4.2, S1.3, SE7.7). Histological observations in these sections were indicative of both the aforementioned conditions (haemorrhagic bone apposition and inflammatory bone reactions) (see Table 6.1). In all of these sections, the bone was extremely thickened in cross-section, and histological investigation revealed different severities of resorption

Table 6.1 Differential diagnosis on macroscopic level and microscopic findings of pathological lesions.

Individual	Age (years)	Sex	Differential diagnoses on macroscopic level	Microscopic findings	Final diagnosis
GLD N8.4	J	M	Osteoid osteoma with nidus, cortical osteoblastoma, ossified hematoma	Demarcated and radiating bone apposition	Ossified hematoma most likely associated with scurvy
GLD N34.13	YA	M	Osteochondroma, ossified hematoma	Demarcated and radiating bone apposition	Ossified hematoma most likely associated with scurvy
GLD N38.5	YA	M	Cortical osteoblastoma, ossified hematoma, treponemal disease	Demarcated and radiating bone apposition	Ossified hematoma most likely associated with scurvy
GLD S2.4	MA	Fe	Ossified hematoma, treponemal disease	Demarcated and radiating bone apposition	Ossified hematoma most likely associated with scurvy
GLD SE7.3	YA	M	Ossified hematoma	Demarcated and radiating bone apposition	Ossified hematoma most likely associated with scurvy
GLD SE7.9	MA	M	Osteomyelitis, ossified hematoma	Demarcated and radiating bone apposition	Ossified hematoma most likely associated with scurvy

M=male, F=female, J=juvenile (11-19 years), YA=young adult (20-34 years), MA=middle adult (35-49 years)

Table 6.1 (cont.) Differential diagnosis on macroscopic level and microscopic findings of pathological lesions.

Individual	Age	Sex	Differential diagnoses on macroscopic level	Microscopic findings	Final diagnosis
GLD N74.7	MA	M	Treponematosis, Non-specific osteomyelitis	Osteomyelitic bone reaction	Treponematosis
GLD N8.5	YA	M	Healed periostitis, ossified hematoma	Demarcated and radiating bone apposition	Ossified hematoma most likely associated with scurvy
GLD NOP3/4.2	YA	M	Treponematosis	A combination of demarcated bone apposition and osteomyelitic bone reaction	Possible treponematosis and hemorrhagic bone apposition
GLD S1.3	YA	M	Osteoid osteoma with nidus, cortical osteoblastoma ossified hematoma, treponemal disease	Combination of demarcated bone apposition and osteomyelitic bone reaction	Possible treponematosis and hemorrhagic bone apposition
GLD SE7.7	YA	M	Osteo-periostitis, early ossified hematoma	Combination of demarcated bone apposition and osteomyelitic bone reaction	Possible treponematosis and hemorrhagic bone apposition
GLD N31.E.1	MA	M	Ossified hematoma	Normal	Normal
GLD S2.9	MA	M	Periostitis	Normal	Normal
GLD SE7.4	MA	M	Periostitis	Normal	Normal

M =male, F=female, YA=young adult (20-34 years), MA=middle adult (35-49 years)

holes/canals indicative of inflammatory bone changes. Apart from these lytic changes to the cortical bone, a still distinct, although interrupted, original periosteal surface, represented by the original circumferential lamellae, was present with radiating appositional bone on top of it.

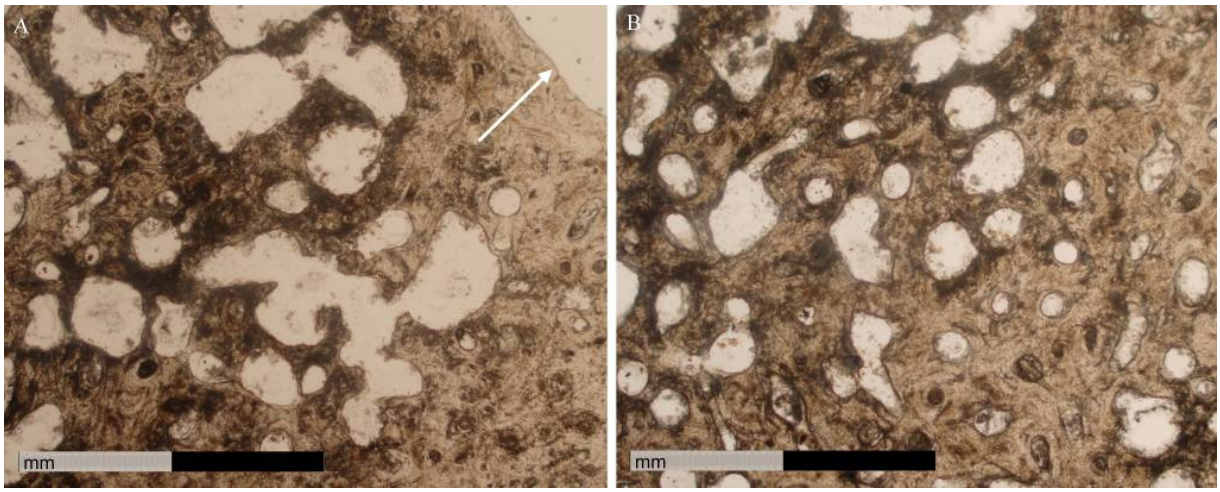


Figure 6.9 Destruction of cortical bone caused by an infectious condition. Periosteal surface indicated by an arrow in A.

Histological results proved macroscopic diagnoses wrong in three cases (GLD N31.E.1, S2.9, SE7.4). In all of these cases, externally striated bone surfaces and possible slight subperiosteal bone reactions were observed during macroscopic investigation. These lesions were thought to be indicative of either non-specific periostitis, early haemorrhagic bone changes, or periosteal remodeling as a result of the strenuous physical activity mine workers were exposed to on a daily basis. Histological investigation revealed that no pathological changes were present in or on the bone.

6.4 Discussion

Controversy exists regarding the accurate diagnosis of pathological conditions through microscopic evaluation of pathological lesions found in skeletal material (Murray & Kodicek, 1949; Blondiaux *et al.*, 1994; Schultz, 2003; Maat, 2004; Von Hunnius *et al.*, 2006). According to Schultz (2003), pathological conditions affecting bone can be distinguished from each other on the basis of their histomorphology on a microscopic level. Infectious diseases such as non-specific osteomyelitis, leprosy and treponemal disease are said to have identifiable characteristics on a microscopic level, making differentiation between these conditions more reliable (Schultz, 2001, 2003; Von Hunnius *et al.*, 2006).

Earlier studies, such as those by Martin and Armelagos (1979) and Putschar (1966), however, suggest that bone can only react in two non-specific ways. According to this argument, two types of cells are responsible for the morphological structure of bone on a microscopic level: osteoblasts and osteoclasts. The first is responsible for the formation of new bone, and the second for the resorption of bone. Remodelling of bone, be it due to a normal or pathological stimulus, is accordingly controlled by the relationship between the osteoblasts and the osteoclasts, one causing the deposition of bone and the other the resorption. Therefore, the basic development of specific histomorphological features for each disease seems impossible.

When considering the two diseases primarily investigated in this histological analysis, being ossified haematomas, probably due to scurvy and treponemal infection, it is clear that they are in two very different categories of bone changes. Individuals suffering from scurvy may develop subperiosteal haematomas on their weightbearing bones, especially on the tibiae and fibulae (Murray & Kodicek, 1949; Auferheide & Rodríguez-Martín, 1998; Maat, 2004). It should be mentioned here that although the ossified haematomas observed in this study can most likely be associated with scurvy, these lesions may also be trauma-related. The histologcal characteristics would however be similar, since the described histological features are indicative of ossified haematomas regardless of their cause. What is important to notice, though, is that the lesions developing due to the haemorrhagic reaction occur due to the ossification of the subperiosteal haematoma on top of the original bone surface. Therefore, it only involves the haematoma, and the underlying bone is not affected. This is exactly what can be seen on a microscopic level. The original cortical bone as well as the external circumferential lamellae are unaffected by the lesion.

Ossified haematoma formation induced by scurvy was well-described after convincing experiments in guinea pigs by Murray and Kodicek (1949), in a study on mid-diaphyseal thickenings of the tibia. Although this is an animal study, it is very valuable since it describes changes occurring during the ossification of a subperiosteal haematoma in the only other mammal incapable of producing its own vitamin C, like humans. According to this study, once the animals further recovered from the scorbutic state, the initial deposited appositional bone, which had a radiating trabecular structure, was remodeled into compact bone while still retaining its radiating characteristics. Thus, once normal levels of vitamin C were restored and retained, the density of the appositional bone increased.

Results obtained during the investigation of pathological lesions from the Kimberley population showed the same pattern of trabeculae formation. Remodeling of the appositional bone by filling in the openings between the trabeculae, as was observed in the guinea pigs, can be seen in humans too. Accordingly, three stages of ossified haematoma formation and remodeling are proposed.

In phase I, the bony, loosely-arranged trabeculae radiate from the original periosteal surface to the lifted periosteum. It should be kept in mind that this radiating structure will only be visible in cross-section, and that these trabeculae are actually more or less longitudinally arranged within the lesion. The original cortical bone as well as the external circumferential lamellae was still intact and unaffected by the pathological process. Looking at a cross-section with the naked eye, the appositional bone seemed extremely porous and clearly visible. It is proposed that this phase will be present during the early stages of ossification of a haematoma, and thus shortly after the restoration of normal levels of vitamin C in the diet.

Phase II could be recognised by the filling-in of the openings between the trabeculae. The original cortical bone, circumferential lamellae and appositional bone were still clearly distinguishable from each other. The appositional bone now had a more compact bone structure, when examined macroscopically on cross-section. In contrast to what was observed in phase I, longitudinal plates of bony lamellae now filled in the openings in the trabecular bone, resulting in the appositional bone having a regular though still radiating appearance on cross-section with no Haversian bone. This proposed phase characterizes the early stages of remodeling of an ossified haematoma after normal levels of vitamin C have been restored in the diet.

In phase III, extensive remodeling of the appositional bone could be observed. The relatively regular appositional bone structure observed in phase II had been replaced by a scattered formation of Haversian systems. The external circumferential lamellae, which represented the original periosteal surface in the previous two phases, became interrupted and were often no longer visible microscopically. Regardless of the extensive remodelling, the radiating structure of the appositional bone stayed visible on cross-section during microscopic investigations under polarised light. It is proposed that this phase is characteristic of long-standing ossified haematomas; the older the haematoma, the more extensive the remodeling of the appositional bone, as was also seen in the guinea pigs (Murray & Kodicek, 1949).

Schultz (2003) and Von Hunnius *et al.* (2006) identified certain histological structures termed 'grenzstreifen' and 'polsters', respectively, as "useful indicator[s] with which to diagnose chronic treponematoses by microscopy" (Schultz, 2003:92). These structures could not be identified in the sections taken from the tibia of an individual affected by treponemal disease, although they were visible in samples thought to be affected by both ossified haematomas and lesions indicative of treponematosis. Several reasons for the absence of these structures are proposed.

Firstly, the sections were slightly infested with a fungus, making the visualisation of the morphological structures difficult (see Figure 6.7). It also limited the use of polarised light, which would have made visualisation of the original circumferential lamellae easier and more reliable, should it be have been present. Another factor that should be considered is that the literature describing these histological features is unclear. Schultz (2003:91), for example, described 'grenzstreifen' as "a very fine line or narrow ribbon-like structure that is the original external surface of the bone shaft", yet the figure associated with this description in fact indicates the normal external circumferential lamellae of the cortex. Von Hunnius *et al.* (2006) on the other hand referred to 'grenzstreifen' as cement lines, although osteocyte lacunae are clearly visible within the 'grenzstreifen' in the figures exhibiting this feature.

Secondly, it is possible that these structures simply were not present in the specific part of the lesion from which the section was taken. In a study conducted by Von Hunnius *et al.* (2006) on the histological identification of syphilis, it was found that the structures described by Schultz (2003) are extremely variable in shape and distribution. Accordingly, positive diagnoses by using the presence of these features proved to be highly dependent on the part of the section investigated. Lastly, these structures may not be exclusively associated with treponematosis. As already mentioned by Schultz (2003), these characteristic structures are also visible in lesions caused by leprosy and haematogenous non-specific osteomyelitis. Features very suggestive of the described structures were also noted in the sections made from changes caused by ossified haematomas in this study.

Microscopic investigations of lesions that developed due to treponemal disease revealed that the sections were extremely porous, with huge resorption holes/canals scattered throughout the sample. No clear distinction could be made macroscopically or microscopically between the original internal trabeculae and the cortical bone due to the porous nature of the sections. Although the sections were clearly enlarged on cross-section,

no traces of the original periosteal surface or new appositional bone could be identified - only general osteoclastic resorption changes (lysis) were present.

According to Blondiaux *et al.* (1994), bone affected by leprosy presented with a large amount of osteoclastic lacunae, giving the bone a porous appearance, and little to no normal Haversian bone was observed. This picture is very similar to that seen in the macroscopically diagnosed treponemal lesions from Kimberley, and it is therefore proposed that infectious changes in bone are most likely very similar on a histological level regardless of the specific condition that caused the osteomyelitis. Therefore, although histological features could not confirm the apparent presence of treponematosis in this study, it was helpful in identifying general osteomyelitic changes clearly distinguishable from ossified subperiosteal haematomas. It was only in conjunction with macroscopic investigation and a clear description of the distribution pattern of the lesions across the skeleton that this osteomyelitis could be attributed to a specific infectious disease, treponematosis.

Four individuals in this study presented with a histological picture indicative of more than one pathological condition. These results emphasized the importance of differential diagnoses of lesions observed during macroscopic investigations.

It was interesting to note that, in three other cases, an incorrect diagnosis of the presence of disease was made by means of gross morphological analysis only. Striations and possible slight subperiosteal bone growth were observed on these bones. Histological sections indicated no pathological changes to the structure of the bone, suggesting that these tibiae were, in fact, normal. This has far-reaching implications for palaeopathological studies, since it may be possible that the pathological condition 'periostitis' particularly is over-diagnosed. This observation needs to be followed up in future studies.

6.5 Conclusion

Pathological lesions, diagnosed macroscopically as resulting from possible scurvy, treponematosis or non-specific periostitis, on the anterior tibiae of 19th century mine workers from Kimberley, were microscopically examined.

Ossified haematomas could be characterized by microscopically unaffected original cortical bone and apposed external radiating trabeculae with or without a horizontal interconnection on the outside surface. Three phases of ossified haematoma formation and

remodelling, as once described in guinea pigs, were proposed in humans, with each stage resulting in gradual bone remodeling from loosely arranged radiating trabecular bone to more compact Haversian bone, while still retaining a radiating bone structure.

Histological features such as the 'grenzstreifen' and 'polsters' described by Schultz (2003) could not be identified in the sections macroscopically diagnosed to be affected by treponemal infection. One possible explanation may be that these structures are not exclusively associated with treponematosis. It was proposed as very likely that the same histological picture will be observed in samples taken from lesions caused by non-specific osteomyelitis, treponematosis and leprosy, since the development of osteomyelitic changes has been described as characteristic in all of these diseases (e.g. Blondiaux *et al.*, 1994; Ortner, 2003).

Thus, it was concluded that although histological investigations could not aid in the diagnosis of specific infectious diseases, such as the syphilitic lesions observed in this study, it was valuable in distinguishing between infectious lesions and those formed by the ossification of subperiosteal haematomas.

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