

December 2015

# Distinguishing Venereal Syphilis from Other Treponemal Infections on the Human Skeleton

Antoinette Elizabeth Fafara-Thompson  
*University of Wisconsin-Milwaukee*

Follow this and additional works at: <https://dc.uwm.edu/etd>



Part of the [Biological and Physical Anthropology Commons](#)

---

## Recommended Citation

Fafara-Thompson, Antoinette Elizabeth, "Distinguishing Venereal Syphilis from Other Treponemal Infections on the Human Skeleton" (2015). *Theses and Dissertations*. 1030.  
<https://dc.uwm.edu/etd/1030>

This Thesis is brought to you for free and open access by UWM Digital Commons. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of UWM Digital Commons. For more information, please contact [open-access@uwm.edu](mailto:open-access@uwm.edu).

DISTINGUISHING VENEREAL SYPHILIS FROM OTHER TREPONEMAL INFECTIONS  
ON THE HUMAN SKELETON

by

Antoinette E. Fafara-Thompson

A Thesis Submitted in  
Partial Fulfillment of the  
Requirements for the Degree of

Master of Science  
in Anthropology

at

The University of Wisconsin - Milwaukee

December 2015

# DISTINGUISHING VENEREAL SYPHILIS FROM OTHER TREPONEMAL INFECTIONS ON THE HUMAN SKELETON

by

Antoinette E. Fafara-Thompson

The University of Wisconsin - Milwaukee, 2015  
Under the Supervision of Professor Fred Anapol

The Treponemal diseases of yaws, endemic and venereal syphilis are capable of producing skeletal lesions during the late stages of infection. Due to the relatedness within the *Treponema* species all three diseases produce similar skeletal pathologies, making the classification of one specific treponemal disease versus another extremely difficult. This study investigates the skeletal pathologies associated with the treponemal infections of yaws, endemic and venereal syphilis in order to determine the skeletal lesions limited to only venereal syphilis. This study concludes that in order to distinguish treponemal diseases one must look beyond just the skeletal lesions and take into account the age of the individual, geographical origin of the remains, and the overall severity of lesions. Further, the caries sicca lesions when combined with these factors can indicate that skeletal lesions are caused by venereal syphilis rather than yaws or endemic syphilis.

To my parents  
and my husband,  
without your support  
this would never have been possible

## TABLE OF CONTENTS

<b>List of Figures</b>	v
<b>Introduction</b>	1
<b>Statement of the Problem</b>	3
<b>Treponema Bacterial Species</b>	6
Evolutionary Theory	7
<b>Non-Venereal Effects on the Skeleton</b>	11
The Pinta Discussion	11
Yaws	12
Endemic Syphilis	24
Summation of Skeletal Involvement of Non-Venereal Infections	28
<b>Venereal Syphilis</b>	30
Endemic Syphilis v. Venereal Syphilis	30
Infection & Stages of Venereal Syphilis	31
<b>Venereal Syphilis and the Skeleton</b>	33
Gummatous Lesions	34
Non-gummatous Lesions	35
Cranial Vault	35
Facial Bones	40
Tibia	43
Other Notable Bone Involvement	46
Neuropathic Arthropathy - Charcot Joints	49
Summation of Skeletal Involvement of Venereal Syphilis	51
<b>Conclusions</b>	52
Significance of Research and Further Research	57
<b>References</b>	59

## LIST OF FIGURES

Figure 1. Microscopic image of <i>Treponema pallidum</i>	6
Figure 2. Evolutionary development of Treponemal infections	10
Figure 3. Course of yaws lesions	16
Figure 4. Rhinopharyngitis mutilans	19
Figure 5. Gangosa of nose and palate in late yaws	20
Figure 6. Juxta-articular nodules of yaws	20
Figure 7. Elbow joint of child with yaws prior to treatment	21
Figure 8. Elbow joint of child with yaws after twenty two weeks of treatment	22
Figure 9. Elbow joint of child with yaws after thirty-one weeks of treatment	22
Figure 10. Dactylitis of phalanges	23
Figure 11. Polydactylis in early yaws	23
Figure 12. Sabre Tibia of endemic syphilis	26
Figure 13. X-ray of arm and leg from child with endemic syphilis	27
Figure 14. Frontal and parietal bone lesions of tertiary syphilis	36
Figure 15. Caries sicca of the skull	37
Figure 16. Syphilitic saddle nose	40
Figure 17. Healed destruction of the nasal cavity	42
Figure 18. Normal tibia versus sabre shin of venereal syphilis	45
Figure 19. Radiograph of sabre tibia	45
Figure 20. Full skeleton with extensive syphilitic involvement	48
Figure 21. Syphilitic lesions of ribs and sternum	49

Figure 22. Charcot joint of venereal syphilis	50
Figure 23: Classification and probable causes of caries sicca lesions on the human skeleton	55

## Introduction

Today “infectious diseases remain the major cause of death worldwide, and are an incalculable source of human misery and economic loss” (Inhorn and Brown, 1997:3). The severity of an infectious disease depends on a number of factors, including the pathogenicity of the infection agent, the form of transmission, immunological strength of host, age, sex, genetics, etc. (Roberts, 2000). Treponemal diseases are no exception.

Treponemal infections are caused by spirochete bacteria in the genus *Treponema* (Mann and Hunt, 2012). On the basis of geographical and diagnostic variations, treponemal infections include four main types: pinta, yaws, endemic and venereal (including congenital) syphilis (Mann and Hunt, 2012). There has been some debate about if the bacteria responsible for the four infections are in fact different species, or rather clinical and environmental variations of one another (Roberts and Manchester, 2005). In fact, until the late seventies *Treponema carateum* (pinta), *Treponema pertenue* (yaws), *Treponema pallidum endemicum* (endemic syphilis) and *Treponema pallidum* (venereal syphilis) were believed to exhibit the same physical structures and were also indistinguishable on the basis of lab investigations (Roberts and Manchester, 2005). There still exists some possibility that these treponemal diseases are varying manifestations of the same bacteria. Therefore, different infections would have to be explained by a combination of intrinsic and extrinsic environmental factors (Roberts and Manchester, 2005).

There is a close relationship between the *Treponema* genus, therefore, treponemal diseases manifest in similar forms both clinically and on the human skeleton. As a result, in the past, the identification of specific treponemal infection from a single or small sample of bones was considered albeit impossible (Aufderheide and Rodriguez-Martin, 1998). In order to distinguish

treponemal infections using the human skeleton, relies on researchers having as complete of a skeleton as possible in order to minimize potential error due to the extremely similar clinical manifestations of treponemal infections (Aufderheide and Rodriguez-Martin, 1998).

## **Statement of the Problem**

At this point in time it is largely thought that there is no distinct pathological characteristic exhibited in the skeleton of individuals suffering from venereal syphilis that uniquely and undoubtedly distinguishes tertiary stage venereal syphilis from other treponemal infections, including endemic syphilis (bejel) and yaws. As a result, it is almost impossible to determine, based on skeletal material alone, which treponemal infection is being displayed on the skeleton without further indicators, such as rashes or lesions, on the skin or through bacterial testing.

This paper examines the effects the treponemal diseases of yaws, endemic syphilis, and venereal syphilis have on the human skeleton. Specifically, on distinguishing the skeletal pathology of tertiary stage venereal syphilis from the similar skeletal pathology of other treponemal infections. The goal of this study is to present ways to distinguish skeletal lesions attributed to venereal syphilis from endemic syphilis and yaws on the human skeleton, and to determine skeletal lesions that are unique to venereal syphilis that will further distinguish venereal syphilis on the human skeleton from other treponemal infections. It is important to note that the treponemal infection pinta has purposely been excluded due to its lack of osseous involvement, which will be discussed in further detail later.

To begin, this paper will examine the bacterial cause of treponemal infections followed by a brief discussion of the theory surrounding if treponemal infections are caused by one single bacteria or separate bacteria species. Followed by the analysis of skeletal involvement in both the non-venereal treponemal infections of yaws and endemic syphilis, and the skeletal involvement of venereal syphilis. Concluding with ways in which one can distinguish tertiary stage venereal syphilitic skeletal lesions from the similar lesions seen in yaws and endemic syphilis, as well as a

discussion as to why this is significant in times treponemal infections are easily treated with antibiotics.

Venereal syphilis the focus of this study, instead of bejel or yaws, because one third of individuals infected with syphilis that is then left untreated will inevitably manifest some forms of tertiary syphilis (Wu et al., 2000). Bone lesions, as a result of tertiary syphilis, often develop between two to ten years after the initial infection. In a majority of cases, “more than one bone is affected and the involvement [of the skeleton] tends to be bilateral” (Ortner, 2003:279). The bones that are most commonly affected in the tertiary stage of venereal syphilis infection include the bones of the cranial vault, the nasal cavity, and the tibiae (Mann and Hunt, 2012).

Tertiary Stage venereal syphilis is the central focus of the study because this is largely the only stage during which the skeleton will show signs of infection. While there has been some research (Hansen *et al.*, 1984; Park *et al.*, 2014) to suggest bone lesions may be present in the secondary stage, the presence of bone lesions at this stage is extremely rare. This is due in part to the fact that bone involvement in the second phase will likely not leave lasting changes on the bone (Ortner, 2003).

Distinguishing venereal syphilis in the skeleton from other treponemal infections is an important contribution to a number of fields of study including biological anthropology, archaeology, medical practice, and epidemiology. There is a widespread geographical distribution of treponemal infections, therefore, it is imperative to know which specific disease is present in what populations. Further, while other treponemal diseases usually exhibit milder symptoms, venereal syphilis is the first treponemal infection to have evolved to not only sustain itself in varying climates, but to alter its mode of transmission based on the changing climate

(Bollet, 2004). Venereal syphilis is also the severest treponemal disease and the only one to impact neurological function in the later stages of infection (Roberts and Manchester, 2005).

## Treponema Bacterial Species

The bacteria responsible for treponemal infections belongs to the family Treponemataceae (Perine *et al.*, 1984). More specifically, the bacterium that causes the non-venereal treponemal infection of yaws is *T. pertenue*, while endemic syphilis is caused by the infection of *T. pallidum endemicum*, and pinta by *T. carateum*. (Perine *et al.*, 1984). All three organisms are identical morphologically, and are not able to be seen through a standard microscope (Perine *et al.*, 1984). In addition to the non-venereal diseases, the bacteria *Treponema pallidum* is the infectious cause of venereal syphilis.

All treponemal infections are caused by a spirochete, or spiral shaped (Figure 1) free-living bacteria from the genus *Treponemata* (Mann and Hunt, 2012; Willcox, 1964).

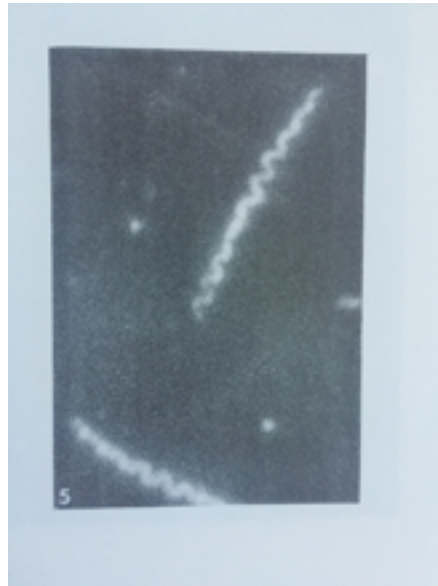


Figure 1: Microscope image of *Treponema pallidum* showing spiral shape (Di Virgilio *et al.*, 1970:15).

*Treponemata* are found throughout nature and have been found in humans in the “mouth, alimentary tract, bronchi, around the urethral orifice, and in the vagina” (Willcox, 1964:135). It is important to note that the same bacteria *T. pallidum* that causes endemic syphilis is identical to

the bacteria that causes the venereal form of syphilis. The primary difference is that as part of a venereal syphilis infection, later stages are characterized by cardiovascular and neurological complications (Perine *et al.*, 1984). Thus, while clinically endemic syphilis is similar to venereal syphilis, it is morphologically more similar to Yaws (Perine *et al.*, 1984). *T. pallidum* (and the other *Treponema* species responsible for yaws, bejel and pinta) are all obligate human parasites. Therefore, they are only found and adapted, to living extremely well in humans (Radolf & Lukehart, 2006).

*Treponemata* is believed to have originated in Africa several hundred thousand years ago, living on the decaying matter from both vegetation and organic sources (Hudson, 1958). It likely first came into contact with humans by being introduced through broken skin in a hot, humid environment in which the bacteria thrive (Hudson, 1958). As the bacteria dispersed across the globe and encountered different climates, environments, people and sanitary conditions, it evolved into its varying forms (Hudson, 1958).

## **Evolutionary Theory**

Before beginning to look at the skeletal pathology associated with non-venereal treponemal infections and which lesions distinguish each treponemal infections from one another, it is important to acknowledge that one of the major questions surrounding treponema is if clinical symptoms are the results of one or a number of different bacterial species (Harper *et al.*, 2008). There has been some debate about if the bacterial species responsible for the various infections are in fact different species or simply clinical and environmental variants of one another (Roberts and Manchester, 2005). The bacteria in question (*Treponema carateum*, *Treponema pertenue*, *Treponema pallidum endemicum* and *Treponema* subspecies *pallidum*), until the late seventies,

were thought to exhibit the same structures and were indistinguishable in the laboratory setting (Roberts and Manchester, 2005).

Research has shown a difference between the bacteria that causes venereal syphilis and the bacteria responsible for non-venereal treponemal infections. However, the differences found within a segment of the DNA does not code for proteins and as a result, are not believed to result in any varying clinical manifestations (Ortner, 2003).

If one single bacterial species is responsible “for all four clinical syndromes, then the clinical differences between the syndromes must be explained by other factors that can affect the expression of infectious disease” (Ortner, 2003:273). These factors can include age of the host, age of onset, differences in immune reactivity, health of the host, the biology of the pathogen and the pathogens reaction to the host (Ortner, 2003). For example, *Mycobacterium leprae*, the causative agent of leprosy, can cause a number of different responses within a host (Ortner, 2003). On the other hand, if more than one bacteria is responsible for the diseases, then the differences between the pathogens become important when understanding the clinical manifestations of the disease (Ortner, 2003).

There are many other diseases that can result in a wide range of pathological responses from one individual to the next, most notably leprosy, as mentioned before. As with leprosy, often it is the host’s individual immune response that will determine the severity of the pathogen rather than independent factors (Ortner, 2003). Factors that can impact the expression and severity of infectious disease includes age of the host, age at onset, exposure to pathogens, overall health and diet of the host, method of infection, social factors such as population density and sanitary conditions (Ortner, 2003). Furthermore, traits of the pathogen itself, such as the pathogens response to the host’s immune system, levels of reproductively and the pathogens

ability to withstand harsher environments or treatment from antibiotics, can also impact the severity and expression of an infectious disease (Ortner, 2003).

As Ortner (2003) discusses, if more than one bacteria is responsible for the differences between treponemal diseases, it becomes more important to distinguish differences between the pathogen to understand differences between its clinical manifestations.

This paper will work under the assumption that each treponemal infection is caused by one of the four different bacterial species, all of which belong to the same family and genus. However, it is highly possible that while each disease is caused by a distinct species of bacteria, that in the past all four of these subspecies may have evolved from a single species. There still exists some possibility that if the treponemal diseases including yaws, pinta, endemic and venereal syphilis, are varying manifestations of the same bacteria, but the infection would have to be explained by a combination of intrinsic and extrinsic environmental factors (Roberts and Manchester, 2005).

In many parts of the world, syphilis is not a venereal disease, rather, it exists in a milder endemic form. Endemic syphilis (also referred to as bejel), similar to yaws, is commonly spread through children through skin to skin contact, as well as through the sharing of eating and drinking utensils (Willcox, 1964). Both yaws and bejel were common childhood diseases not associated with any sexual contact. However, in colder and drier climates where skin to skin contact was limited and as sanitation conditions improved, endemic syphilis evolved to be spread venereally by sexual contact as its main means of transmission (Willcox, 1964).

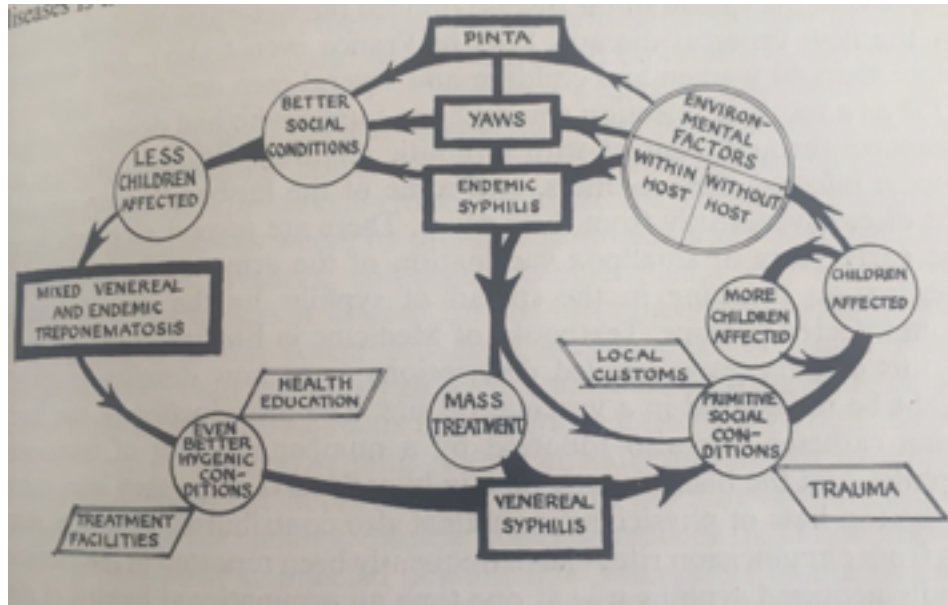


Figure 2: Evolutionary development of Treponemal infections (Willcox, 1964:131).

The evolutionary view of treponemal infections (Figure 2) is based on the idea that all treponemal infections are inherently related and each evolved into different infections due to largely environmental and sanitation factors (Willcox, 1964). Specifically, tropical climates are more suited towards milder treponemal infections such as yaws and bejel due to the increased chances for skin to skin contact (Willcox, 1964), whereas colder and drier climates with less chances for skin to skin contact, evolved mucous membrane to mucous membrane transmission (Willcox, 1964).

### **Non-venereal Effects on the Skeleton**

On the whole, treponeme bacteria have a higher tendency to affect bones that have minimal overlying soft tissue. This may be due in some part to the fact that these bones are often more prone to trauma (Ortner, 2003). In addition, it has been hypothesized that because bacteria reproduces at high levels at specific temperatures, that the bones located closer to the surface may be slightly cooler and thus a better environment for the bacteria to reproduce and grow (Ortner, 2003). Therefore, treponemal infections on the skeleton are distinguishable from other diseases that effect the skeleton, due to the tendency for bones closer to the surface of the skin to be impacted by treponema. Furthermore, the most distinguishing bone feature of treponemal infections is the presence of crater like lesions with radiating stellate lines that extend from the lesions, and are found in almost all examples of treponemal infections (Ortner, 2003). As a result, determining lesions that are caused by a treponemal infections is not as difficult, but determining which of the three treponemal infections that exhibit skeletal pathologies is much more difficult.

### **The Pinta Discussion**

Pinta (*Treponema carateum*) is the mildest treponemal infection, and is found primarily in the American tropics, and in parts of Central and South America, such as Colombia and Mexico (Binford and Connor, 1976; Mann & Hunt, 2012). Pinta initially presents as a rash, which then exhibits pigment alterations before spreading in the secondary stage (Mann & Hunt, 2012). The tertiary stage is classified by the depigmentation of the lesions (Mann & Hunt, 2012). Pinta differs from yaws in that it alters the pigment mechanism of the skin, causing extensive pigmentation on the surface of the skin (Hudson, 1958).

Pinta is caused by the bacteria *T. carateum*, and until 1938 was thought to have been a fungal infection, rather than bacterial, until a Cuban patient was shown to be infected by treponemes that were indistinguishable from those that cause syphilis and yaws (Perine *et al.*, 1984). Unlike yaws or endemic syphilis, pinta is seen largely in young adults from age fifteen to thirty that exhibit skin lesions for long periods of time (Perine *et al.*, 1984). The mode of transmission is not exactly known but is thought to be the results of skin to infected lesion contact (Perine *et al.*, 1984). Pinta is the only non-venereal treponemal infection that has never been shown to cause bone lesions (Mann & Hunt, 2012). As a result, for the purpose of this paper I will only focus on the skeletal pathology associated with yaws and endemic syphilis.

## **Yaws**

Yaws is a non-venereal contagious treponemal disease that is also found in Central and South America (Willcox, 1964). Prior to the development of antibiotics, yaws was common throughout the world in humid tropical regions with significant rainfall and high temperatures (Binford and Connor, 1976). Yaws is largely seen only in children and exhibits similar characteristics of endemic syphilis (Willcox, 1964). Yaws is found in warm humid regions, including the Caribbean, Dominican Republic, and Jamaica, as well as in Central American countries, including Bolivia, Brazil, Columbia, and Venezuela. Yaws is also widespread in West Central Africa and throughout East Africa (Willcox, 1964).

As previously mentioned, the organism that causes yaws is *T. pertenue*. It very similar to the bacteria *T. pallidum* that causes endemic syphilis, and *T. carateum* that causes pinta (Perine *et al.*, 1984). *T. pertenue* cannot be cultured in the lab, and multiplies very slowly inside humans with only one multiplication, roughly every thirty hours. Further, it is easily killed by drying,

increased temperatures, and exposure to oxygen (Perine *et al.*, 1984). *T. pertenue* can only survive outside of a host for a short time and is very susceptible to penicillin and erythromycin antibiotics (Hoeprich & Jordan, 1989). Yaws, unlike venereal syphilis, cannot cross the placenta and therefore cannot result in congenital infections. Yaws produces lesions on the skin, bone and in the cartilage but does not affect deeper organs (Perine *et al.*, 1984).

Similarly to endemic syphilis, individuals are more commonly infected with yaws as children, in particular from ages two to ten (Willcox, 1964). Infection is passed through skin to skin contact with the moist skin lesions of an infected individual. In addition, individuals may also become infected through trauma and even through small cuts on the skin (Willcox, 1964). Using a similar process as endemic syphilis, yaws commonly affects people who live in overcrowded conditions, with a lack of clothing and poor sanitary conditions (Willcox, 1964).

After incubating for anywhere from two to eight weeks, initial lesions characteristic of a yaws infection begin to appear (Willcox, 1964). The primary lesions develop at the initial infection site and has been referred to as the mother yaw (Binford and Connor, 1976). The mother yaw “is a raised papillomatous, hyperkeratotic structure which eventually forms a clean shallow ulcer” (Binford and Connor, 1976:114). The mother yaw is almost always located on an area of skin that is normally exposed and not covered by clothing (Binford and Connor, 1976). Furthermore, these early lesions are characterized by an initial eruption of papules on the skin, which if left untreated, will begin to heal after three to six months (Willcox, 1964). Yaws infections can be categorized as early and late stage yaws. In early stage yaws, an individual exhibits erythematous papules on the skin that can burst open and spread, making early stage yaws very contagious. These lesions are most commonly found on exposed surfaces of skin such as the legs or feet, but can involve any area of the body (Willcox, 1964).

Bone lesions in yaws are rare, and reported in only between five to fifteen percent of cases and are largely considered indistinguishable from other treponemal infections (Mann & Hunt, 2012; Ortner, 2003). However, bone lesions are more common in yaws than either endemic or venereal syphilis (Ortner, 2003). These lesions are more commonly associated with long bones including the tibia, fibula, femur ulna, humerus and radius. In some cases, bone lesions have been reported in the spine, clavicle hands, feet, skull, ribs, and rarely the pelvis (Ortner, 2003).

Due in part to yaws being mainly a childhood disease, active lesions are largely seen only in children. These lesions may result in underlying bone lesions that may heal entirely, leaving no visible bone defects by the time the child is an adult (Ortner, 2003).

Bone involvement, while mainly seen in late stage yaws, is possible in the early stage. In the early stage of yaws, bones may be affected by osteitis and periostitis (Willcox, 1964). Periostitis is the thickening of the periosteum that may be shown in X-ray and osteitis are areas of rarefaction on the bone. It is important to note that at the early stage these lesions are often found in conjunction with one another and are often not destructive. As part of which the bones may exhibit visible signs of thickening and may be accompanied by osteo-articular pain and fever (Willcox, 1964). Furthermore, because early stage bone lesions are often not destructive, upon healing, there is very little bone alteration that could be pinpointed as due to yaws lesions (Hoeprich & Jordan 1989).

Some cases of early yaws may exhibit the hypertrophic osteitis of the nasal processes on the superior maxilla (Willcox, 1964). This causes a bony thickening to develop on each side of the nasal cavity which, over time, will enlarge and after many years can result in the obstruction of the nostrils, difficulty with vision and may even begin enlarging the area near the eye orbits (Willcox, 1964).

Once the initial lesions heal, most individuals either remain in the latent stage or undergo a spontaneous cure. However, some individuals can develop late stage lesions of either the skin or bone more than five years post infection (Willcox, 1964). Bone lesions in the late stage can include “gummatous and hypertrophic periostitis, osteitis and osteoperiostitis” (Willcox, 1964:283). In the later stages of infection, gummatous periostosis and osteomyelitis can develop and present as pathologically identical to that seen in tertiary stage syphilis. However, the periostosis and osteomyelitis in yaws is normally not as severe as in tertiary stage syphilis (Mann & Hunt, 2012).

Unlike the early stage lesions, late stage skin and bone lesions are solitary and destructive (Hoeprich & Jordan, 1989). Damage includes irregular swelling as well as rarefaction and thickening of the bone that can be detected through X-ray (Willcox, 1964). Both superficial and extensive ulcers form as a result of the breakdown of cutaneous papillomas, which can extend from the tissue into bone (Hoeprich & Jordan, 1989). As a result, bone lesions are directly related to deep ulcerated lesions of the skin and are largely seen in the limbs, hands and skull (Hoeprich & Jordan, 1989). In addition, bone pain in infected individuals is common during this stage and individuals with severe ulceration of the skin may also involve the underlying bone (Willcox, 1964). After healing, it is normal for a prominent bony thickening to be detectable both clinically and through radiological imaging (Hoeprich & Jordan, 1989). Late stage bone lesions are found in approximately ten percent of yaws patients (Hoeprich & Jordan, 1989).

Hackett (1951) extensively studied the lesions of yaws observed in Uganda from 1937-1938. Hackett (1951) classified lesions according to the stage of lesion (Figure 3) that was observed.

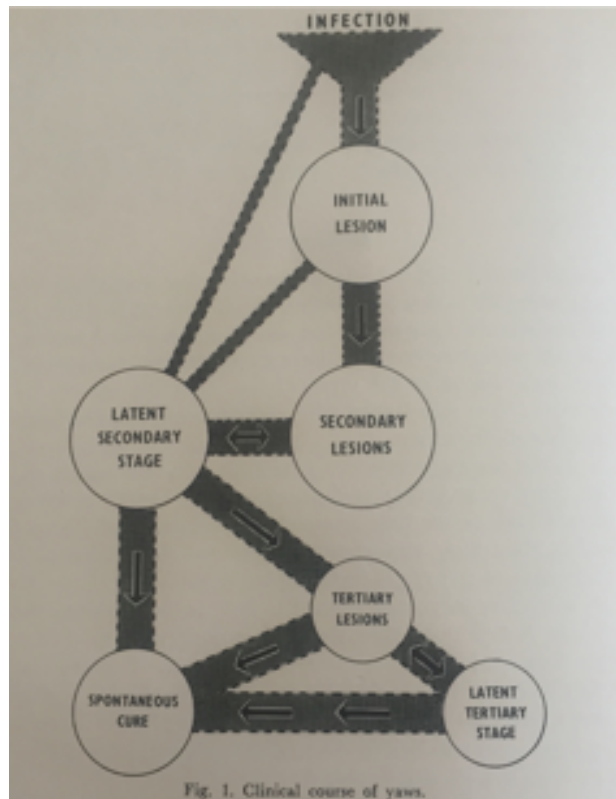


Figure 3: Clinical course of yaws lesions (Hackett, 1961:10).

Initial lesions were found at the site of infection and were similar to secondary lesions.

Secondary lesions present at other sites beyond the infection site were characterized by a granular appearance as a result of the spirochetes bacteria that causes Yaws (Hackett, 1951). It is important to note that skin lesions are rarely destructive to the skin and leave only small scars (Hackett, 1951).

As the infection progresses, destructive ulcerations appear on the skin, which when healed, will leave pigmented scars on the surface of the skin. These lesions are classified as tertiary (late stage) lesions, and they are present only after the appearance of secondary (early stage) lesions (Hackett, 1951). Furthermore, in late stage lesions no active bacteria will be found within these lesions. Tertiary or late stage bone lesions are associated with tertiary skin lesions, but there is the possibility for tertiary bone lesions when no skin lesions are present (Hackett, 1951).

As shown in Hackett's (1951) extensive research, pathological bone changes are possible

in both the early and late stages of a yaws infection. Through radiographs on one hundred and fifty two patients with active skin lesions, Hackett (1951) was able to observe pathological changes in the bone. These changes can be divided into two stages active and inactive changes; active changes included rarefactions and periosteal deposits, while inactive changes included cortical thickening, bony expansion and the classic sabre tibiae (Hackett, 1951).

Rarefactions were indicated by increasing levels of translucency of the bones in the radiographs, and cortical rarefactions were more frequently observed (Hackett, 1951), specifically, the rarefactions were divided into diffuse or focal. Diffuse rarefactions showed an “ill-defined granular loss of cortical density” (Hackett, 1951:23), followed by thick periosteal deposits. In addition, smaller focal rarefactions may appear in association with the increasing bone deposits that do not become larger over time.

As Willcox (1964) states, “Secondary bacterial infection through the skin may lead to massive new bone formation and to the production of sequestra. Although the long bones are usually involved, others, e.g. single phalanges, may be affected” (1964:283-284). With late stage yaws, permanent bone lesions and changes to the structure of the bones are often permanent. Furthermore, curving of the long bones have been reported. For example, as with endemic syphilis, persons with yaws can develop the classic sabre tibiae characteristic of treponemal infections (Willcox, 1964).

One of the most common skeletal characteristics seen in yaws infections is that development of “boomerang leg” (otherwise referred to as sabre tibia) (Mann & Hunt, 2012). Sabre Tibia “is a term applied to a general anterior bowing of the tibia without necessarily any other gross changes in the bone” (Hackett, 1951:28). This bending of the tibia is very similar to sabre tibia exhibited in congenital syphilis (Ortner, 2003). Boomerang leg/sabre tibia develops

from the hypertrophy of the anterior surface of the tibia (Mann & Hunt, 2012) and normally begins before the age of fifteen (Ortner, 2003). Rarely, if ever, does the fibula show any hypertrophy like the tibia (Mann & Hunt, 2012).

What is described as true and pseudo-bowing are possible in the tibias. True bowing is typically seen in younger individuals and is classified by abnormal curving of the long axis of the tibia (Ortner, 2003). While pseudo-bowing is perceived bowing due to reactive bone formation on the anterior and medial surfaces of the long axis without actual distortion to the long axis that is commonly seen in adults (Ortner, 2003). Further, it is extremely rare to see any involvement or bowing of the fibula. Beyond the tibiae, in some cases, the radius and ulna may exhibit some form of bowing. However, this is likely not caused by yaws alone and may be due to other postrachitic deformities. Therefore, bowing of the radius and ulna should not be used as a basis from which to declare a yaws infection (Ortner, 2003).

In addition to Hackett (1951), similar research into treponemal infections in Western Micronesia found that out from a sample of 468 individuals, 17-27% of adults and 10% of children exhibited skeletal pathology associated with yaws (Trembly, 1996). In particular, this study found that the most commonly affected bone was the tibia and the next most commonly affected bone was both the ulna as well as the frontal bone in 50% of the identifiable cases (Trembly, 1996). The lesions on the frontal bone were classic caries sicca lesions indistinguishable from the caries sicca seen in venereal syphilis (Trembly, 1996).

Changes to the skull include chronic lesions that show a central destruction with surrounding reactive bone formation that results in a crater type lesion referred to as caries sicca (Ortner, 2003). These lesions start with a cluster of holes that penetrate the outer table and are associated with the gumma, which is the primary area containing the bacteria (Ortner, 2003).

Beyond caries sicca lesions of the frontal bone, a condition that can be seen in yaws, as well as endemic and venereal syphilis, is the development of Rhinopharyngitis mutilans. This condition is the result of gummatous processes forming in the nasopharynx, which then spreads and destroys both the soft and bone portions of the nose, soft palate, uvula, and hard palate. In extreme cases, this can result in the complete destruction of the nose (Figure 4), forming a large hole on the face of the individual (Willcox, 1964). This condition results from the formation of destructive ulcerations on the nose and palate (Figure 4) referred to as gangosa. The damage then extends to the nasal cavity and hard palate, destroying the underlying bone (Hoeprich & Jordan, 1989).

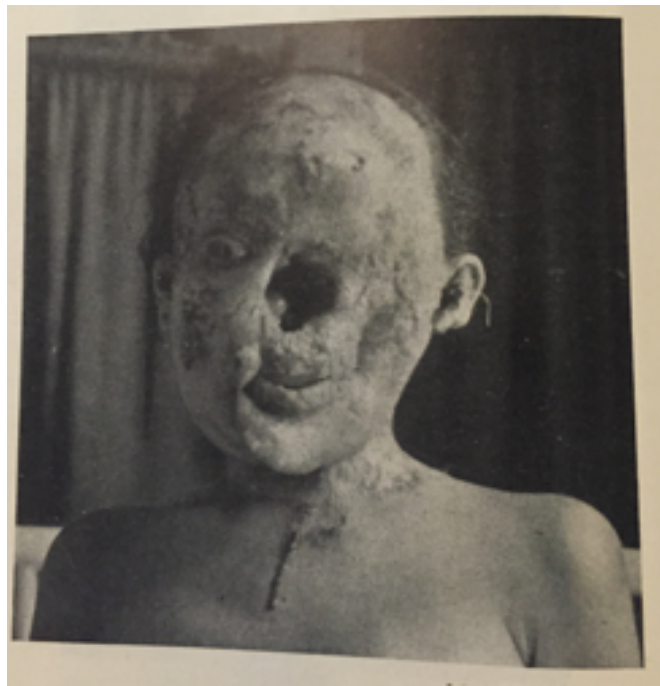


Figure 4: Rhinopharyngitis mutilans with complete destruction of the nasal cavity (Willcox, 1964:286).



Figure 5: Gangosa: ulcerations of the nose and palate seen in late yaws (Hoeprich & Jordan, 1989: 1027).

Finally, another clinical manifestation of yaws is the swelling of joints (Ortner, 2003). Juxta-articular nodules in major joints (Figure 6) are commonly seen in untreated late stage yaws, as well as later stages of both endemic and venereal syphilis (Binford and Connor, 1976).

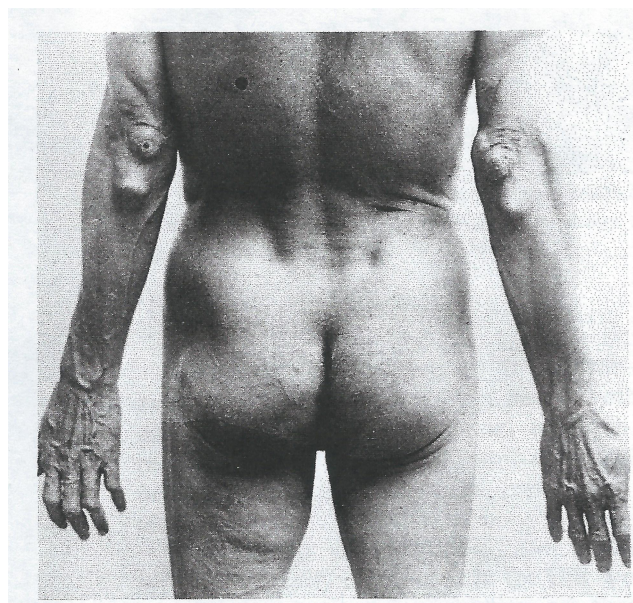


Figure 6: Juxta-articular nodules characteristic of untreated late stage yaws (Binford and Connor, 1976:116).

Hackett (1951) observed a fourteen-year-old boy that had contracted yaws seven years prior and displayed swelling in his left elbow for one year. A Radiograph of the joint (Figure 7) showed “thick stratified periosteal deposits on both surfaces of the humerus” (Hackett, 1951:135-136). There was also a potential thickening of the olecranon fossa (Hackett, 1951). The boy was treated with 0.4g of bismuth oxide and seen again at 22 weeks (Figure 8) and 31 weeks (Figure 9), at which point he received no further treatment. Each time the lesions had worsened with localized thickening and erosion with limited movement of the joint (Hackett, 1951).



Figure 7: Elbow joint of 4 year old boy with yaws, showing thick periosteal deposits on the surface of the humerus (Hackett, 1951:135).



Figure 8: Same individual from Figure 6: 22 weeks later (Hackett, 1951:136).

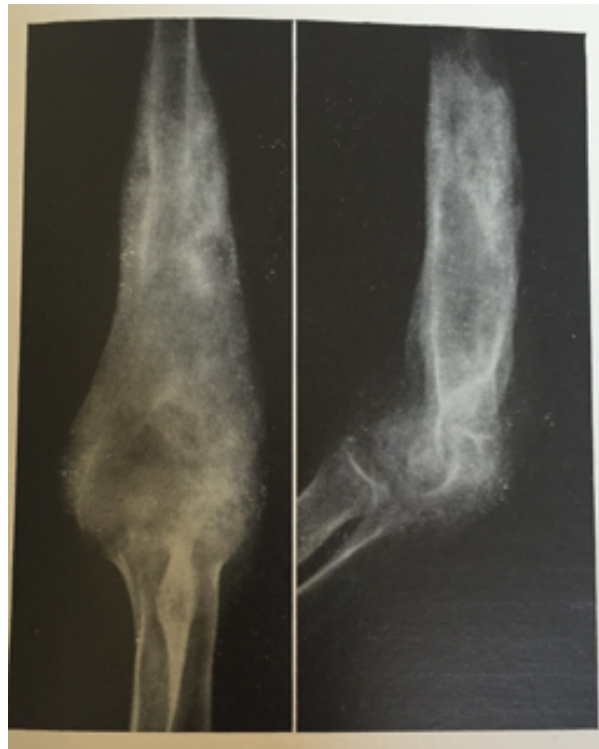


Figure 9: Same individual from Figure 6: 31 weeks later (Hackett, 1951:137).

In addition to the elbow, the boy showed similar lesions developing in his left femur (Hackett, 1951). Another example, observed by Hackett (1951) was the destructive dactylitis of individual phalanges (Figure 10) in a twelve-year-old girl. Swelling in the interphalangeal joints caused the phalanges to become angled and impairing function (Ortner, 2003). Hoeprich & Jordan (1989) also note that polydactylitis is a characteristic of yaws (Figure 11).

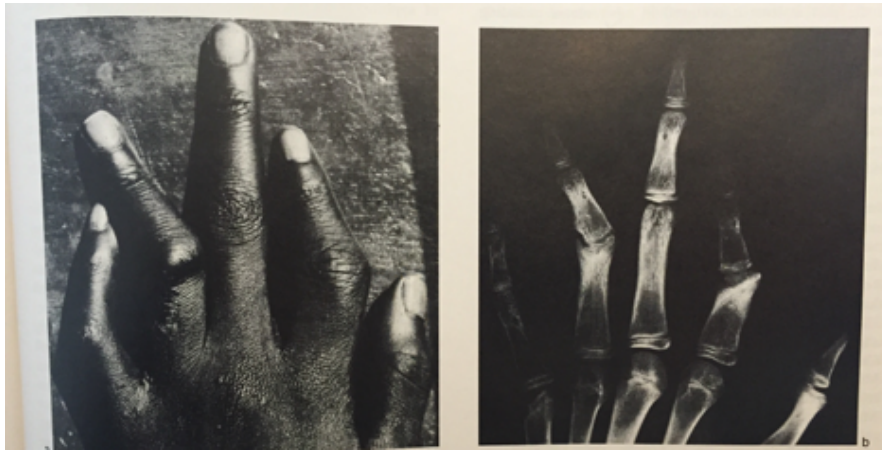


Figure 10: Destructive dactylitis of phalanges causing enlarged interphalangeal joints resulting in the phalanges becoming angled (Ortner, 2003:277).



Figure 11: Polydactylitis in early stage yaws (Hoeprich & Jordan, 1989:1025).

When compared to the other treponemal diseases, yaws can be distinguished by the increased rate at which it results in both early and late bone lesions, as well as nasopharyngeal lesions and articular nodules (Binford and Connor, 1976). Non-venereal syphilis, on the other hand, has less primary lesions and more involvement of the mucosal surfaces, on the whole this will result in fewer and less severe skeletal lesions (Binford and Connor, 1976). Venereal syphilis also exhibits similar lesions, as seen in yaws and non-venereal syphilis, but also “invades the eye, brain, and the large arteries which may cause disabling or fatal lesions” and will be discussed further later (Binford and Connor, 1976:112).

### **Endemic Syphilis**

Endemic syphilis, otherwise referred to as bejel (Ortner, 2003), is transmitted through direct skin-to-skin contact, as well as indirectly through contact with infected objects, such as eating utensils. Non-venereal syphilis is largely found in the Old World, primarily in the Middle East and Africa (Ortner, 2003), but has been known to exist in Syria and Bosnia (Binford and Connor, 1976). It is important to note that endemic syphilis, unlike other treponemal disease, is not seen in tropical climates (Binford and Connor, 1976). It is primarily found in poor rural populations with most cases involving children (Willcox, 1964). Children ages two to fifteen (Perine *et al.*, 1984) are more commonly infected with endemic syphilis due to a closer association with their family members and through playing in close contact with other children (Willcox, 1964). Furthermore, endemic syphilis can be introduced to a family either through a non-related child, or from an adult who acquired either sexual or non-sexually transmitted syphilis, and then spread it to a child (Willcox, 1964). Children who do not acquire endemic syphilis as a child may acquire it as an adult, non-venereally, through the sharing of eating

utensils and smoking instruments, etc. (Willcox, 1964).

Due to the almost identical relationship between the *T. pallidum* that causes venereal syphilis and that of endemic syphilis, researchers believe that the differences between them may be caused by subtle variations in the exact bacterial strain (Perine *et al.*, 1984). It is important to note that when endemic syphilis is acquired at an early age, it does provide immunity from later infection from venereal syphilis (Perine *et al.*, 1984). While endemic syphilis is largely attributed to *Treponema pallidum*, Binford and Connor (1976) argue that the clinical manifestations of endemic syphilis are so similar to yaws that the bacterial species responsible for these infections should be classified as *Treponema pertenue*, the bacteria responsible for yaws. It is also possible that endemic syphilis is an intermediate infection between yaws and venereal syphilis, and as previously mentioned, the levels of sanitation and living conditions will impact whether syphilis is venereal or non-venereal within a population (Mann & Hunt, 2012).

Unlike venereal syphilis, a primary chancre at the site of infection is extremely uncommon (Willcox, 1964). Rather, endemic syphilis largely presents in the secondary stage. Patches of mucous on the lips and palate, as well inside the mouth, on the tip of the tongue, on the nostrils or in the larynx are common (Hoeprich & Jordan, 1989; Willcox, 1964). In addition, rashes on the skin, which can be widespread on the body are severe, and are also characteristic of the secondary stage. Early lesions on the skin are present anywhere from six months to a year after infection and heal slowly (Willcox, 1964). Relapses can occur, but are not common for endemic syphilis. Once the lesions are healed a long period of latency normally follows. However, there is the possibility for tertiary lesions to develop long after the initial infection has healed (Willcox, 1964).

The tertiary lesions of endemic syphilis are caused by gummatous changes in the skin and

underlying bone. In particular, these changes arise in individuals who have suffered some form of trauma to the skin and/or bone, or in individuals who have been repeatedly exposed to multiple treponemal infections (Willcox, 1964).

Skeletal changes of endemic syphilis resemble those changes seen in acquired or late stage congenital syphilis (Ortner, 2003). These skeletal changes largely consist of periosteal bone deposits that result in fusiform enlargement but with very little medullary changes (Ortner, 2003). Reactive bone formation on the tibia (Figure 12) can result in sabre tibia common to treponemal infections (Ortner, 2003).



Figure 12: Sabre Tibia from individual with endemic syphilis (Ortner, 2003:279).

Furthermore, periostitis and gummas have been seen in both the short bones of the hands and feet, as well as destructive nasal lesions leading to the destruction of the hard palate (Ortner, 2003). While changes to the bone are common, overall, the changes associated with endemic

syphilis are less severe than those of yaws (Giacani & Lukehart, 2014).

In the skeleton, late lesions of endemic syphilis include syphilis osteitis with increasing gumma formation and periostitis (Willcox, 1964). These changes are most commonly seen in the long bones, specifically in the tibiae and the ulna. However, changes in the frontal bone, clavicles, and bones of the hands can be involved (Willcox, 1964). For example, Figure 13 (Hudson, 1958:133) shows an X-ray of a 6-year-old Bedouin boy who had contracted endemic syphilis one year prior. In this figure, you can see both the bones of the arm and leg. For example, one can see the thickening of the shafts as well as the increased areas of density. In addition, it also shows new bone completely filling the medullary cavity. While technically in the early stage of endemic syphilis, this figure shows all stages of involvement, including periosteal proliferation, areas of destruction, and endosteal changes (Hudson, 1958).

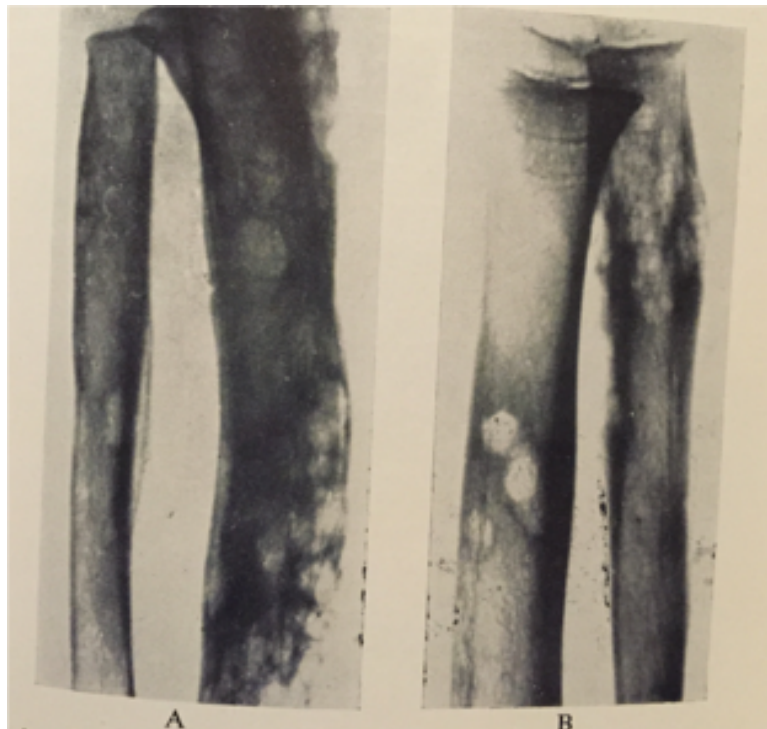


Figure 13: X rays of both arm and leg bones from a 6 year old Beduin boy with endemic syphilis (Hudson, 1958:133).

With endemic syphilis, thickening of the periosteal surface can arise almost simultaneously in a number of bones. Initially, “new bone is deposited parallel to the long axis of the bone: later it is laid down at right angles giving it a fuzzy appearance [on radiographs]” (Willcox, 1964:272). Due to the new bone deposition, bone deformation can occur.

As previously stated, one of the most common deformities noted in treponemal infection is the bowing of the tibiae, due to the anterior thickening of the tibiae, known as sabre tibiae. This type of anterior thickening can also be indicative of endemic syphilis (Willcox, 1964). In addition, the bone may exhibit localized lesions with swelling as cortical rarefaction in the smaller bones. Furthermore, any lesions on the bone may be associated with ulceration on the surface of the skin (Willcox, 1964). Finally, late stage endemic syphilis that results in bone pathology may also involve the joints, resulting in ankylosing arthritis particularly in the elbows (Willcox, 1964).

Congenital bejel, if one can argue, has ever existed is extremely rare and albeit nonexistent today (Hoeprich & Jordan, 1989). Due to the young age that individuals are most likely to contract endemic syphilis, it is unlikely that a girl will become pregnant at such an age and pass on the disease. Further, if infected with endemic syphilis, by the time they reach childbearing age the infection is no longer active (Hoeprich & Jordan, 1989).

### **Summation of Skeletal Involvement of Non-Venereal Infections**

To summarize, there are three non-venereal treponemal infections: pinta, yaws, and endemic syphilis. Each of these infections is caused by a subspecies of bacteria within the genus *Treponema* (Willcox, 1964). Only yaws and endemic syphilis exhibit skeletal pathology (Mann & Hunt, 2012). Due to the fact, that all three non-venereal infections are believed to have

stemmed from one original bacterial species, there are many similarities in the clinical manifestations of these infections (Ortner, 2003), especially, when looking at the skeletal pathologies associated with both yaws and endemic syphilis. Yaws and endemic syphilis both exhibit early and late stages of infection with skeletal involvement. Furthermore, long bones including the tibia, ulna, humerus, clavicles, as well as cranial bones, are most commonly affected (Willcox, 1964). One of the most common skeletal pathologies associated with yaws and endemic syphilis is the development of sabre tibia. However, sabre tibia is more commonly found in yaws infections than endemic syphilis. As a result, the presence of sabre tibia cannot be used as a means through which to distinguish yaws or endemic syphilis from each other, or from venereal syphilis.

Both infections result in periosteal bone growth and reactive bone formation as well as exhibiting periostitis and gummas on the bone (Hackett, 1961; Willcox, 1964). In summation, the skeletal pathologies of non-venereal treponemal infections such as yaws and endemic syphilis are extremely similar and hard to distinguish. However, when comparing the severity of lesions, yaws is thought to exhibit more severe lesions when compared to endemic syphilis (Giacani & Lukehart, 2014). While difficult to distinguish between non-venereal infections when compared to venereal treponemal infections i.e., syphilis research has shown that the overall skeletal pathologies are more severe in venereal versus non-venereal infections (Giacani & Lukehart, 2014). Therefore, based on the severity of lesions present one may be able to make a differentiation between yaws and endemic syphilis once venereal syphilis has been eliminated, however, one cannot rule out venereal syphilis based on lesions severity alone.

## Venereal Syphilis

### Endemic Syphilis vs. Venereal Syphilis

Syphilis is a very adaptable disease. It has been suggested that syphilis, in its early forms, was endemic and not spread by sexual contact, nor was it generally fatal. Rather, syphilis existed in a milder form similar to yaws that was passed by skin-to-skin contact (not sexual contact) (Bollet, 2004). It was not until sanitation conditions improved that syphilis mutated to become the sexually transmitted venereal form of the disease we associate it with today (Salt and Pye, 2004). This was likely the result of the fact that in colder climates people were required to wear more clothes limiting infection by skin-to-skin contact, as previously stated. (Tremblay, 1996). It has even been theorized that sailors on Columbus's crew contracted the endemic form during their travels in the new world, which then mutated into the venereal form, once the crew returned home, due to the changes in climate and sanitation (Stirland, 1991). However, Stirland (1991) documents a case of syphilis from Norwich prior to contact with the new world, adding to the ever-changing debate if venereal syphilis originated in the New World or Old.

To review, Endemic syphilis is caused by infection from *Treponema pertenue*, which is closely related to the bacteria *Treponema pallidum*, which is the cause of venereal syphilis (Binford and Connor, 1976). Endemic syphilis is found in warm, semi-arid environments and is spread through close (non-sexual) contact with infected individuals through kissing, touching etc., or through contact with contaminated objects (Mann and Hunt, 2012). Venereal syphilis is found throughout the world in a variety of climates, and it is spread either through sexual contact or from a mother to her child in the womb (congenital syphilis) (Mann and Hunt, 2012). The only pathological difference in the skeleton between adult venereal syphilis and congenital syphilis are the lesions of congenital syphilis are present on immature bone that is still growing

(Collins, 1966). Endemic syphilis (as well as yaws and pinta) is a disease with a childhood onset, while venereal syphilis, due to the sexual nature of the disease, has an adult onset (except in cases of congenital syphilis) (Roberts and Manchester, 2005). Interestingly, while it is possible for venereal syphilis to be passed from mother to fetus in the womb, this type of infection is not known in endemic syphilis (Roberts and Manchester, 2005), possibly because endemic syphilis often has a childhood onset and often the affected individuals are not yet reproducing (Roberts and Manchester, 2005). Overall, endemic syphilis, also known as bejel, exhibits symptoms more closely related to those of yaws than of venereal syphilis (Binford and Connor, 1976).

One of the most significant differences of venereal syphilis compared to endemic syphilis and all other treponemal diseases is the involvement of the central nervous system associated with venereal syphilis (Roberts and Manchester, 2005). In the later stages of syphilis, infected individuals may suffer a number of neurological symptoms such as altered gait and insanity (Roberts and Manchester, 2005).

### **Infection & Stages of Venereal Syphilis**

Venereal Syphilis is normally divided into three primary stages of infection (Ortner, 2003). Several weeks after infection a distinctive lesion called a chancre develops at the point of infection. The beginning of the first stage is characterized by the development of chancre lesions (Ortner, 2003). The first stage continues with the ulceration of the site of infection (Salt and Pye, 2004). The end of the first stage is marked with the movement of the bacteria into the lymph nodes located near the primary infection site. In the second stage of venereal syphilis, the syphilis causing bacteria is spread throughout the body through the bloodstream, normally resulting in skin rashes and mucous membrane lesions (Ortner, 2003; Salt and Pye, 2004). The

transition from the secondary stage to the tertiary stage is not as distinctive as the transition from the first to second stage. Nonetheless, the tertiary stage is generally accepted as involving larger organs in the body, such as the skeleton (Ortner, 2003).

As part of the tertiary stage, tissue throughout the body suffers widespread chronic inflammation. Further, the tissue may develop a “distinct granulomatous appearance of nodular foci with central liquefying necrosis (gumma)” (Ortner, 2003:278). Also, as part of the tertiary stage, individuals will exhibit lesions in the mouth, inflammation, and pain, as well as possibly exhibiting signs of insanity (Salt and Pye, 2004).

While there has been some research (Hansen *et al.*, 1984; Park *et al.*, 2014) to suggest bone lesions may be present in the secondary stage, the presence of bone lesions in the secondary stage has proven to be extremely rare. This is due in part to the fact that bone involvement in the second phase, such as periostitis with bone formation, is common. However, these changes in the bone will likely not leave lasting changes to the bone (Ortner, 2003). Diagnosing syphilis versus other treponemal infections is difficult due to the fact that all four types manifest similarly in the skeleton (Mann and Hunt, 2012).

### **Venereal Syphilis and the Effects on the Skeleton**

One third of individuals infected with syphilis, that is then untreated, will inevitably manifest some form of tertiary syphilis (Wu *et al.*, 2000). Bone lesions, as a result of tertiary syphilis, often develop between two to ten years after the initial infection. In a majority of cases, “more than one bone is affected and the involvement [of the skeleton] tends to be bilateral” (Ortner, 2003:279). The bones that are most commonly affected include the bones of the cranial vault, the nasal cavity, and the tibiae (Mann and Hunt, 2012). Together these affected bones make up seventy percent of all skeletal bone lesions related to tertiary syphilis (Ortner, 2003). While less common, cancellous bone and bones with high concentrations of hematopoietic marrow, such as the ribs and sternum, can also be affected in addition to other long bones (Ortner, 2003). However, it is important to note that while signs of syphilis are usually found on the bones described, any bone in the body can be affected by and show signs of syphilitic infection (Ortner, 2003). For example, the vertebral column is largely never affected by syphilis. If the vertebral column is involved, it is primarily found in the cervical vertebrae (Ortner, 2003).

Syphilitic lesions are the result of the formation of gummata as well as the result of non-gummatous inflammation attributed to the syphilitic infection (Jaffe, 1972). Lesions are commonly involving bones that are located closer to the surface of the skin and are often associated with trauma (Jaffe, 1972). As Jaffe (1972) discusses, lesions are normally not the result of one traumatic injury. Rather, they are prone to areas of the bone that are repeatedly subject to use or irritation, such as prolonged pressure or friction. However, it is important to point out that lesions can also be found in bones that have never had any trauma or experienced abnormal wear and stress (Jaffe, 1972).

The bone changes exhibited in the tertiary stage can be localized or widespread on the bone and “is the result of either chronic non-granulomatous inflammation or granulomatous (gummatous) process” (Ortner, 2003:280). Normally, it is a combination of both. Furthermore, the inflammation involves the periosteum, cortex and in rare cases, the medullary cavity (Ortner, 2003). Bone lesions that result from tertiary syphilis often have a high osteosclerotic response to the infection (Ortner, 2003). In addition, the areas surrounding these regions, such as the mucosal surfaces, overlying skin and soft tissue show ulceration and lesions as well (Ortner, 2003).

Gummata in bones largely do not appear until years after the initial infection and can also present as non-gummatous periostitis or osteomyelitis. Therefore, both gummatous and non-gummatous lesions can result in bone pathology indicative of a syphilitic infection (Jaffe, 1972).

### **Gummatous Lesions**

Like in other treponemal infections such as yaws and endemic syphilis, gummatous lesions on the bone are primarily associated with gummatous lesions occurring in or on the superficial tissue surrounding the bone (Jaffe, 1972). Gummata can form within both the medullary cavity and the periosteum, but the gummata developing in the periosteum is often much smaller than gummata in the medullary cavity (Jaffe, 1972). Gummata can range in size from extremely small (almost non-visible) to enlarging to fill the entire medullary cavity. Furthermore, “the caseous necrotic material is yellowish in color and has a dry, pulpy, crumbly consistency” (Jaffe, 1972:926). Microscopically gummata is characterized by granulated tissues with enlarged capillaries and interspersed with lymphoid cells (Jaffe, 1972). On the whole, gummata tend to enlarge over time, but can regress or even fully heal. Evidence of healing is in

the encapsulation of gummata by fibrous tissue, which over time will cut off the gummata from other tissues (Jaffe, 1972).

### **Non-Gummataous Lesions**

Non-gummatous lesions can include both Periostitis and Osteomyelitis. Non-gummatous periostitis is often found in late stages of syphilis infections and can involve a minimal area of the bone or as is more often the case, the entire periosteal surface of a bone (Jaffe, 1972). As a result, the bone may show significant medullary inflammation and may cause the bone to become thickened and deformed, especially in long bones such as the radius, ulna, and tibiae (Jaffe, 1972).

Non-gummatous periostitis can occur alone or simultaneously with gummatous lesions of the marrow cavity (Jaffe, 1972). Prior to any periosteal formations developing the periosteum will first become inflamed, exhibiting a thick fibrous layer that will be swollen with large accumulations of lymphoid cells surrounded by nerves and vessels (Jaffe, 1972).

In addition to non-gummatous periostitis, non-gummatous osteomyelitis is often found in the intramedullary gummata. Frequently, found in the intertrabecular spongy marrow cavities of long tubular bones, osteomyelitis will be observed with connective tissue and numerous blood vessels (Jaffe, 1972). Osteomyelitis within spongy bone is usually atrophic and it is uncommon for osteomyelitis to spread and involve the entire marrow cavity or cellular tissues (Jaffe, 1972).

### **Cranial Vault**

One of the most common areas in the skeleton affected by tertiary syphilis is the cranial vault (Ortner, 2003). The lesions found on the skull characterize the most unique diagnostic

feature that separates syphilis from other bone pathology seen in similar treponemal diseases (Ortner, 2003). “The classic triad of cranial syphilis consists of nodes, cavitations, and stellate scars” (Mann and Hunt, 2012:59). Jaffe (1972) describes, “in the skull erosion of the calvarium by gummata has long been regarded as especially characteristic of acquired syphilis” (Jaffe, 1972:930). Furthermore, as Hackett (1976) details, the lesions begin as clustered pits on the frontal bone (Figure 14) and as the disease progresses, lesions will appear on the periphery bones, including the parietals and the nasal bones (Jaffe, 1972; Hackett, 1976; Ortner, 2003).

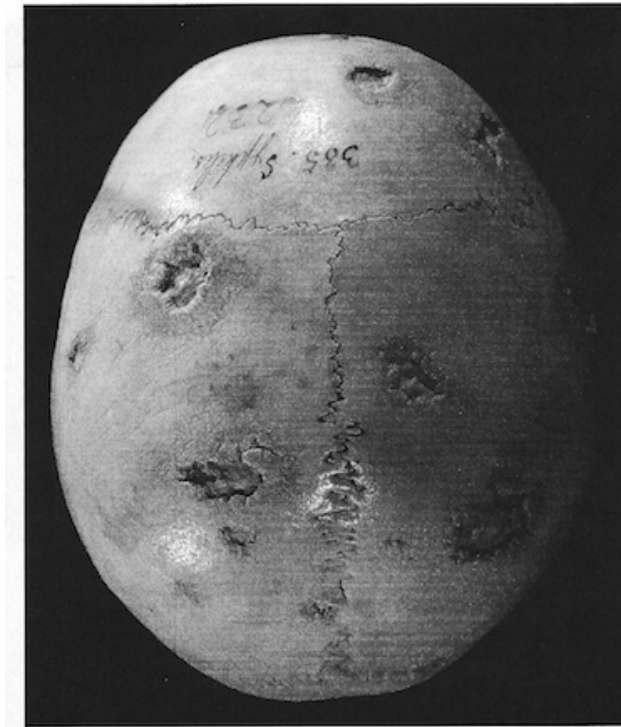


Figure 14: Lesions on the Frontal and Parietal Bones characteristic of Tertiary Syphilis (Ortner, 2003:281).

It is possible for lesions to begin on the parietal bone. However, it is more common that lesions will initiate on the frontal bone followed by one or both of the parietals. Also, the occipital bone rarely exhibits any lesions and only in the most severe cases. Even then infection of the occipital bone is rare (Jaffe, 1972; Ortner, 2003).

The lesions are commonly referred to as caries sicca (Figure 15), and usually begin on the outer table of the skull near the osteoperiosteal border and can penetrate into the dipolē (inner) portion of the skull (Jaffe, 1972; Ortner, 2003).

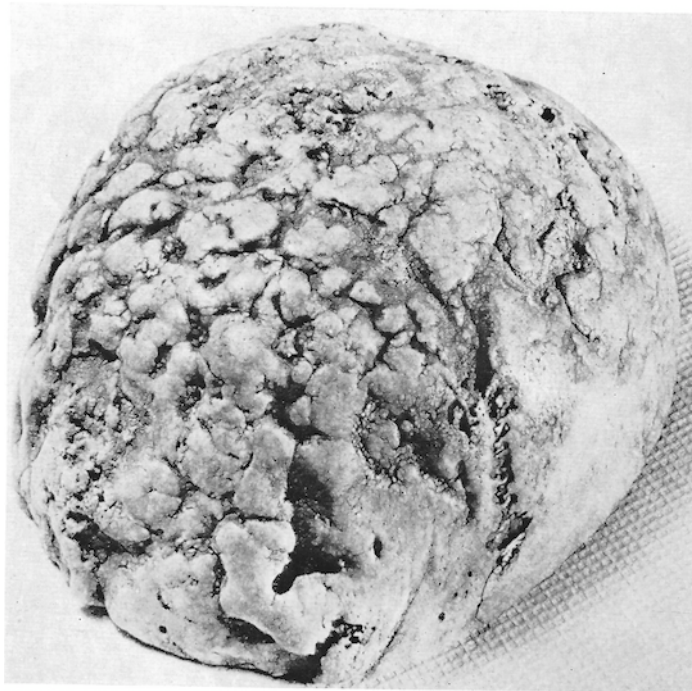


Figure 15: Caries Sicca of the skull, showing extensive bone deformation and regrowth (Hackett, 1976:48).

The term caries sicca is associated with lesions that result from the resorption of cortical bone in areas that have been subjected to gummatous inflammation (Jaffe, 1972). Bone destruction occurs due to the presence of the gummatous inflammation, not the gumma itself. Rather, it is the inflammation that causes the destruction of the bone and the slow resorption process that results in the caries sicca lesions (Jaffe, 1972). The lesions result in destructive remodeling of the outer table and dipolē while in most cases not damaging the inner table. The outer surface of the cranial bones become eroded by the inflammation of the pericranium, from which the inflammation may penetrate to the inner calvarium through the walls of blood vessels extending

from the pericranium through the outer cranial surface (Jaffe, 1972). This destruction of the outer and inner tables results in a worm like appearance often attributed to syphilis remains and characteristic of caries sicca (Roberts and Manchester, 2005).

Two opposing processes occur as part of the erosion of the cranial vault. In the center, the degrading erosion process takes place, while the peripheral condenses. This process impacts the spread and depth of the lesion (Jaffe, 1972). As the bone is eroded, new bone is deposited around the edges of the cavity, resulting in a folded or wrinkled appearance. Finally, as further erosion occurs the newly deposited bone may form an irregular wall on the eroded cavity, and a thin layer of bone will form at the deepest level of the erosion, destroying the dipole (Jaffe, 1972).

In addition to the erosive changes, if the erosion is deep enough into the calvarium, inflammation can extend into the dura mater, cutting off the pericranium and dura matter from its blood supply. As a result, inflammation can spread rapidly, resulting in mass necrosis in addition to the erosive changes. This necrosis can remain on the bone for prolonged periods which can, in extreme cases, result in the breakdown of the overlying skin tissue, making the sequestra visible on the scalp (Jaffe, 1972). At this point, surgical removal of the sequestra is often necessary if the sequestra are separated from the rest of the cranium (Jaffe, 1972).

In his studies Hackett (1976) documents exhibiting various treponemal disease in twenty two medical museums throughout England, Scotland, and Europe. In his samples Hackett (1976) found that out of eighty-five specimens exhibiting a variety of diagnostic definitions of syphilis, the inner surface for the most part had none of the extensive deformities as the outer table. Such remodeling results in the formation of a sclerotic base and elevated sclerotic margin around the lesion (Ortner, 2003). In even severe chronic cases of syphilis specific lesions will heal only to

be replaced by new lesions in the surrounding tissue. The healed caries sicca “leaves a depressed, sclerotic, radially grooved stellate scar” (Ortner, 2003:280). Infection left untreated over a long period of time will therefore result in raised healed nodules as well as deep depressions of the cranial vault (Mann and Hunt, 2012) surrounded by hard remodeled bone (Ortner, 2003).

Additionally, continually recurrent caries sicca can also result in the thickening of the dipolë, even while the inner table shows little to no impact from the infection (Ortner, 2003). It is important to note that while uncommon, it is possible for caries sicca to perforate the entire cranial vault through the outer table, dipolë, and inner vault (Hackett, 1976). Although, as Ortner (2003) notes, in these extreme cases the impact on the inner vault is still less pronounced. According to Hackett (1976), this cycle of the continually appearing and healing lesions of caries sicca creates the jagged, star-shaped depressions and raised nodules that are the most reliable diagnostic determinant of syphilis on the skull (Hackett, 1976).

Rarely Gummatous inflammation of caries sicca can be the direct cause of bone destruction when the bone becomes necrotic. Caries necrotica is caused by the rapid spread of gummatous tissue, which results in necrosis of the bone and the destruction of remaining osseous tissue. How quickly the sequestrum is invaded with the gumma will impact whether the bone tissue can retain its compactness, or if it will become porotic (Jaffe, 1972). This rapid progression can lead to caries necrotica being present where once was caries sicca lesions (Jaffe, 1972).

While cases of cranial erosion in syphilis cases are less common due to the development of effective treatment with antibiotics, the manifestations of syphilis on the cranium, including the caries sicca and the erosion, “is so striking and typical that their recognition at autopsy is

simple” (Jaffe, 1972:933). It is important to note that, especially in older remains, lesions and erosion, due to osteoporosis or even leprosy, can be mistakenly attributed to venereal syphilis.

### **Facial Bones**

The bones of the face usually affected by tertiary syphilis include “the nasal bones, the nasal septum, the hard palate, the turbinates and the lateral walls of the maxillary antrum” (Ortner, 2003:283). These bones are normally linked with the syphilitic lesions associated with the nasal mucosa common to venereal syphilis (Ortner, 2003). Often these bones are destroyed as a result of the syphilitic lesions, resulting in the perforation of the nasal septum, medial walls of the maxillary sinuses, and the hard palate. This results in the breakdown of the nasal cavity with the area of the destruction lined with smooth sclerotic bone tissue (Ortner, 2003). Further destruction of the nasal bridge results in what is referred to as syphilitic saddle nose (Figure 16) (Ortner, 2003:283).

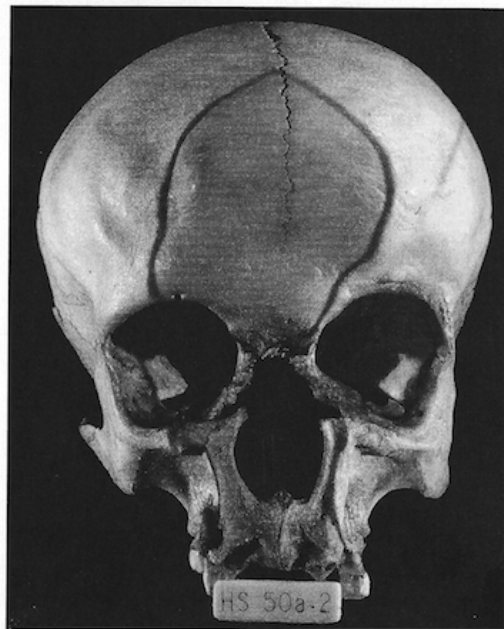


Figure 16: Destruction of the nasal bridge causing syphilitic saddle nose (Ortner, 2003: 284).

While the erosion of the cranium and nasal cavity is rare in modern times, in the past both were quite common in syphilis cases. Gummatous erosion, as well as necrosis of the nasal cartilage and bone, extended from syphilitic ulcers in the nasal mucosa (Jaffe, 1972). Sequestra often formed, destroying the nasal bone and cartilage due to the growth of gummata. Gummatous involvement was the most severe in the posterior and upper regions of the nasal cavity. As a result, the cartilage in the nose, the nasal bones, vomer and ethmoid, and even the upper maxilla, would suffer necrosis (Jaffe, 1972). The degradation of the ethmoid and vomer, regardless of the effects on the nasal bones, destroys the nasal root, resulting in saddle nose (Jaffe, 1972).

Due to the proximity to the frontal bone, the zygomatic bone and orbital walls may also exhibit lesions and destruction. Finally, these lesions have also been shown to penetrate the palate and in rare cases the nasopharyngeal process and the sphenoid (Ortner, 2003). Out of 42 specimens in Hackett's (1976) study, 29 were diagnosed with syphilis and exhibited some form of facial destruction. Many of the specimens examined with syphilis exhibited "empty nasal cavities with smooth lateral walls, presenting a smooth, bored out tunnel-like passageway" (Hackett, 1976:63). Interestingly, most of the individuals who suffer this type of nasal deformation will survive and show evidence that partial or total healing (Figure 17) had taken place while the individual was alive (Hackett, 1976). It is this destruction of the nasal cavity with pronounced healing that Hackett (1976) notes as a main identifier for venereal syphilis.

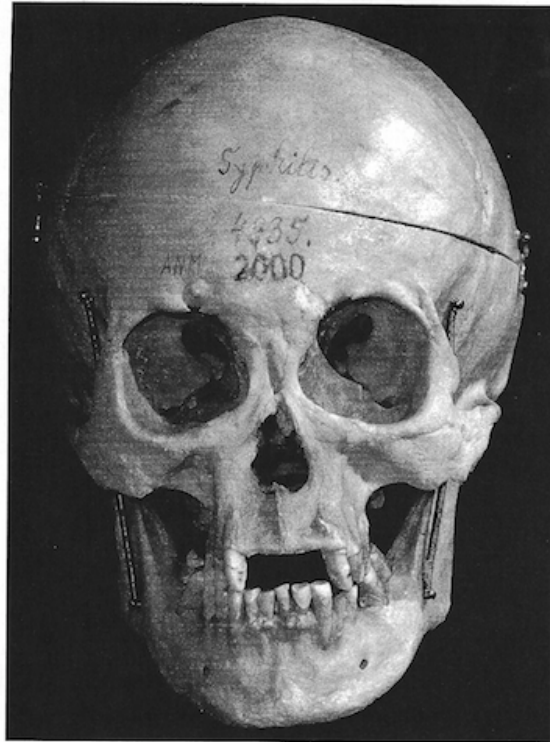


Figure 17: Healed destruction of the nasal cavity (Ortner, 2003:284).

Notably, the changes in the nasal area and hard palate among individuals suffering from venereal syphilis are often not as extreme as nasal destruction characteristic of yaws and endemic syphilis (Roberts and Manchester, 2005). This is significant because the presence of nasal deformation with little to no other characteristics indicative of syphilis may suggest infection from other treponemal disease rather than syphilis especially if in a warmer climate in which other treponemal disease are more common and more easily contracted and spread.

In association with the destruction of the nasal cavity, in some cases the destruction of the nasal cavity can lead to the erosion of the upper jaw, specifically the hard palate (Jaffe, 1972). This is largely attributed to the extension of gummata from the nose to the hard palate below. This deformation of the nasal area and hard palate may continue even after the infection has been treated. As with cranial deformations in older skeletal remains, one must consider the possibility that deformations of the nasal cavity is the result of other pathologies including (but not limited

to) leprosy, lupus and even other treponemal infections such as yaws, which are known to exhibit deformations of the nasal cavity and surrounding area (Jaffe, 1972).

## **Tibiae**

“The tibia is approximately 10 times more often the site of syphilitic lesions than any other long bone of the extremities” (Ortner, 2003:283). Although, pathology seen in the long bones is different from the caries sicca, pitting and destruction seen in the skull, and nasal cavity (Hackett, 1976). As previously discussed, lesions characteristic of syphilis can be divided into two groups: non-gummatous and gummatous osteoperiostitis (Hackett, 1976). Long tubular bones in the skeleton, including the tibiae, exhibit gummatous lesions more often than other skeletal bones. Further, tubular bones exhibit lesions on the interior surface more so than on the posterior surface (Jaffe, 1972). Instead the long bones often show excess bony deposits, causing expansion of the long bones or a bowing effect.

Non-gummatous lesions deposit “placquelike exostoses on the cortex of bone that have a major overlying layer of muscle” (Ortner, 2003:285) and more often than not results in thick heavy bones. The presence of non-gummatous osteoperiostitis is not thought to be characteristic of treponemal infection. Therefore, gummatous osteoperiostitis that is much more commonly accepted as characteristic of syphilis.

Localized gummatous osteoperiostitis exhibits a tumor-like growth of the bone, which results in a “periosteal bony buildup surrounding a scooped-out defect extending into the cortex” (Ortner, 2003:286). In certain cases, these scooped lesions can appear similar to the caries sicca seen on the cranial vault, but the overall gummatous are usually larger and more widespread (Ortner, 2003). It is important to note that fractures as the result of bones weakened from

syphilitic osteoperiostitis is fairly common (Ortner, 2003). Furthermore, the lesions found on the skeleton would have been in conjunction with painful inflamed lesions on the surface of the skin and throughout the dermis and muscle to the bone (Weiss and Joseph, 1951).

Within the medullary cavity of long tubular bones, including the tibia and femur, gummata are not only normally found within the diaphysis portion of the bone, but can also be seen at the metaphyseal ends, as well as at both portions of the bone simultaneously (Jaffe, 1972). Because the gummata is present primarily on the interior of the bone, it may be latent or encapsulated, making it only detectable through imaging even during autopsy (Jaffe, 1972). However, gummata may also be accompanied by pain as well as visible swelling and deformity of the bone. Gummata that spreads throughout large portions of the medullary cavity normally do not become or remain dormant. Rather, it will result in periosteal thickening through new bone formation that can double or triple the circumference of the diaphysis (Jaffe, 1972).

The continued deposition of new bone results in an anterior enlargement of the tibia, resulting in sabre-shin or boomerang leg, as mentioned before (Figure 18) (Mann and Hunt, 2012). It is important to note that this bowing is not due to an actual bending of the tibia, instead this pseudobowing is due to the continued bone growth (Figure 19) on the anterior surface resulting in a bent boomerang type appearance (Mann and Hunt, 2012).



Figure 18: A normal tibia (left) compared to a Sabre-Shin or Boomerang tibiae (right) (Mann and Hunt, 2012:163).



Figure 19: Radiograph showing the excessive bone growth on the anterior surface of the tibia that results in the sabre-shin (Mann and Hunt, 2012:163).

A true bowing of the tibia is possible, but only in association with congenital syphilis (Jaffe, 1972). Sabre tibia, seen in cases of venereal syphilis, can be confused with sabre tibia exhibited in cases of Paget's disease. However, the bowing associated with Paget's disease rapidly merges with the underlying bone and would not be detectable through x-ray. While sabre tibia, due to venereal syphilis, will exhibit layers of bone growth visible on x-ray. Furthermore, tibia deformed due to Paget's disease will show lamellation of the cortex, a widening and uneven medullary cavity, and when looking at histologically, the bone will exhibit a mosaic type architecture (Jaffe, 1972). In addition, the tibia may present with coarse striations and pitting that Hackett (1976) suggests may be a diagnostic of syphilis, although not as concrete as other indicators such as sabre shin and gummatous osteoperiostitis.

Non-gummatous inflammation of the periosteum is more common than inflammation that spreads throughout the bone. This inflammation begins on the inner surface of the periosteum and may cause the overlying skin to be red, swollen, and painful when pressure is applied to the area (Jaffe, 1972). In addition, periostitis can develop and cause severe pain when the infected do not undergo treatment (Jaffe, 1972). Periosteal inflammation that diffuses can affect one portion of a bone, the entire bone, or a number of bones. Diffuse inflammation is primarily seen in the tibia and will result in the cortex being replaced by porous bone tissue and the medullary cavity replaced with spongy bone. Further, it can also result in thick sclerotic growth on the bone with a smooth surface with many pores for blood vessels with an ivory like consistency (Jaffe, 1972).

### **Other notable bone involvement**

As briefly mentioned Stirland (1991) presents a case of venereal syphilis in a set of male remains from a cemetery in Norwich dating back to as early as 1100 AD. This skeleton lacked

cranial and facial bones for examination, and the cranial bones that were present did not show signs of syphilis. However, lesions were found on the distal ulnae and radii as well as both femora, tibiae, and fibulae. In addition, lesions were found on the tarsals and metatarsals on the left side of the individual. In other words, this skeleton exhibited syphilis lesions on a number of bones beyond those of the skull, nasal bones and tibia. Using Hackett's (1976) diagnostic criterion of syphilis, Stirland (1991) notes that the lesions exhibit striate and pitting Hackett (1976) lists as being the result of syphilis.

Tertiary syphilis in the spine is rare with involvement of the vertebral column occurring in association with lesions on other bones, rather than alone (Jaffe, 1972). Vertebral bodies are more often affected than arches and processes and syphilitic lesions are primarily only seen in one vertebrae rather than a number of vertebrae (Jaffe, 1972). Furthermore, cervical vertebrae are more commonly affected than either thoracic or lumbar vertebrae (Jaffe, 1972). This being said, the diagnosis of syphilis based primarily on the vertebral column would be impossible (Ortner, 2003). This is due in part to that if the vertebral column is in fact impacted it will likely exhibit destruction of the vertebrae similar to that of tuberculosis (Ortner, 2003), making it almost impossible to distinguish the two diseases from the vertebral column alone (Ortner, 2003).

Extreme and unusual bone involvement well beyond any other documented human remains have been noted by Ortner (2003) and include two complete skeletons from the Pathology Museum of the University of Strasbourg in France. These two skeletons show extreme skeletal involvement (Figure 20), including lesions on the clavicles and sternum and destruction to the scapula and ribs (Figure 21) (Ortner, 2003).

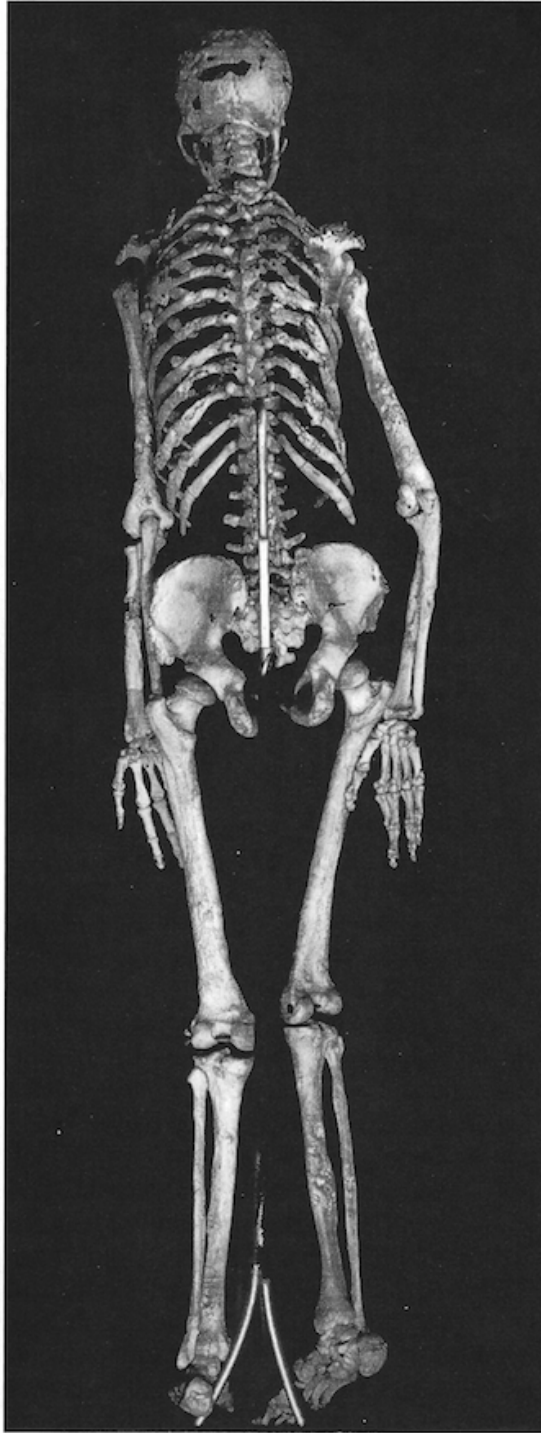


Figure 20: A skeleton exhibiting extreme syphilitic involvement of the entire skeleton (Ortner, 2003:288).

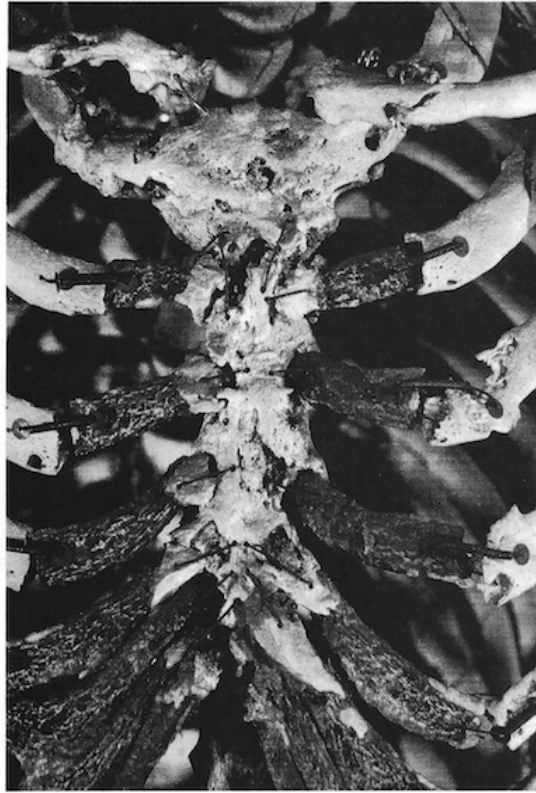


Figure 21: Syphilitic destruction of the ribs and sternum (Ortner, 2003:289).

As Ortner (2003) points out, that while these two individuals do show extreme severity, it is likely that these individuals would have had a “severely compromised immune response to the pathogen” (Ortner, 2003:289), resulting in the extreme skeletal involvement.

Repair and regrowth of bones altered by venereal syphilis is possible. Regrowth of the cortex will appear to have the same architecture as existing bone microscopically, but reconstruction of the interior portions of bone is less likely to occur (Jaffe, 1972).

### **Neuropathic Arthropathy – Charcot Joints**

In addition to the effects on the skull and long bones, it is possible for later stages of syphilis to result in neuropathic arthropathy, otherwise known as Charcot joints. Charcot joints

(Figure 22) are caused by the “mechanical abuse in the absence of normal pain and position sensations combined with abnormal neurovascular control of circulation (Ortner, 2003: 586).



Figure 22: A right ankle exhibiting classic manifestations of Charcot joint (Ortner, 2003:586).

In terms of this paper, Charcot joints are usually the result of later stages of neurosyphilis, resulting in severe destruction and fragmentation of the joint along with destruction of the convex and concave joint ends and degenerative arthritis (Ortner, 2003). The first symptom of Charcot Joint is inflammation, with or without pain. If left untreated the joint may lose its normal contoured shape, resulting in a rattling and popping “bag of bones” type sound from the joint (Weiss and Joseph, 1951:109). Normally any joint in the body can be involved, but most often the joints affected are the knee, hips, and shoulder joints (Ortner, 2003). Interestingly, Weiss and Joseph (1951) discuss that there is an association between the presence of Charcot joints in males that have suffered some form of previous trauma weakening the joint (Weiss and Joseph, 1951).

## **Summation of Skeletal Involvement of Venereal Syphilis**

In short, “The pathological changes caused by *Treponema pallidum* in the bones are a chronic inflammatory infiltrate, sometimes granulomatous and necrotizing, accompanied by bone destruction, and provoking a reactive osteogenesis” (Collins, 1966:220). Venereal syphilis largely affects the skeleton in the later tertiary stage of infection (Ortner, 2003). Venereal syphilis of the human skeleton is commonly associated with the presence of pitting and deformation of the cranial vault, specifically in the frontal and parietal bones (Hackett, 1976). Furthermore, the frontal and parietal bones often exhibit caries sicca, which is thought to be one of the most obvious signs of syphilis (Hackett, 1976).

In addition, venereal syphilis often results in the deformation of the nasal cavity and the surrounding bones, although often the individual affected will survive and show signs of healing (Hackett, 1976). Venereal syphilis is also seen largely in the tibiae, which exhibit gummatous osteoperiostitis and excessive growth on the anterior surfaces of the tibiae known as sabre-shin (Mann and Hunt, 2012). Beyond the bones that are most commonly affected, venereal syphilis can be seen in any bone including the vertebral column, ribs, and sternum (Ortner, 2003). Furthermore, the presence of Charcot joints is often a skeletal effect of neurosyphilis that can be observed in skeletal remains (Weiss and Joseph, 1951).

## Conclusions

In conclusion, when distinguishing treponemal disease on the human skeleton, one must take into account a number of different factors before making a classification. First, one must consider the age of the individual as subadults and adults may exhibit similar lesions but can have different causes of said lesions. Second, one must consider the geographical location (specifically the climate zone) the remains are originating from. Finally, one must consider the severity of the lesions before making a classification of one specific treponemal disease over another.

First of all when determining if skeletal lesions are attributed to yaws, endemic syphilis, or venereal syphilis, one must consider the age of the individual. Yaws and endemic syphilis are primarily diseases of childhood affecting children ages two to fifteen (Willcox, 1964; Perine *et al.*, 1984). On the other hand, Venereal syphilis, due to its sexual transmission, is seen largely in adults. As a result, age of the individual can be used to reinforce classifying one treponemal infection as the cause of lesions over another. For example, an adult exhibiting sabre tibia with severe caries sicca and nasal deformation is more likely to have suffered from venereal syphilis than the childhood infections of yaws or endemic syphilis.

In addition to using the age of the individual to determine a disease classification, when skeletal lesions are similar, one can also look at the geographical location and the climate from which the skeletal remains originate. As established yaws is primarily found in tropical climates (Willcox, 1964), while endemic syphilis is not seen in tropical climates but in poor rural populations with poor sanitary conditions (Willcox, 1964; Binford and Connor, 1976). Venereal syphilis, on the other hand, has been found throughout the globe in non-tropical climates (Mann and Hunt, 2012). Building on the previous classification of age, a young individual exhibiting

sabre tibia from a tropical climate is more likely to have suffered from yaws than venereal syphilis.

Further, the severity of the skeletal lesions may prove helpful in determining one treponemal infection versus another. Overall, the skeletal lesions associated with venereal syphilis are more severe than those of non-venereal treponemal diseases (Giacani & Lukehart, 2014). However, specific areas such as the nasal cavity in non-treponemal diseases tend to exhibit more severe lesions than in their venereal counterparts (Binford and Connor 1976).

As presented, yaws, endemic and venereal syphilis can all exhibit similar lesions on the same bones. All three diseases can exhibit sabre tibia, degradation of the nasal cavity and charcot joints. Therefore, the distinction between the diseases cannot be made based solely on the presence of one or more of these specific pathologies. However, with regards to nasal lesions the nasal changes of venereal syphilis are believed to be less severe than those of both yaws and endemic syphilis (Roberts & Manchester, 2005). As a result, while the degradation of the nasal cavity cannot distinguish yaws from endemic syphilis, the severe degradation of the nasal cavity without the presence (or with less severe lesions) on the frontal bone can rule out venereal syphilis as the cause of the skeletal pathology when also taking into account the age of the individual and the climate the individual originates from.

In addition to and associated with lesions of the tibia, nasal cavity and joints, skeletal lesions on the skull are also possible in all three diseases. This is due in part to the fact that all three diseases are caused by bacterial species that are extremely closely related. However, as Hackett (1976) described the caries sicca lesions on the frontal and parietal bones are the most distinctive characteristic indicative of venereal syphilis. As such, based on the presence of caries sicca lesions in association with other factors, including the age of the individual and the

geographical location that the individual is from, one can make a definitive classification of venereal syphilis as the cause of skeletal lesions versus other treponemal infections. This is due in part to the fact that while all diseases can show skeletal lesions, the caries sicca and stellate pitting in venereal syphilis distinguishes it from all other treponemal infections (Hackett, 1976).

Further, cranial lesions of venereal syphilis are more severe than cranial lesions in yaws and endemic syphilis (Binford & Connor, 1976). However, as mentioned, nasal lesions while normally present are not as severe as those seen in yaws infections. Therefore, if one is presented with a skeleton that exhibits severe cranial lesions and mild nasal cavity deformations, versus mild cranial lesions and severe nasal deformations, the individual was more likely suffered from venereal syphilis. If the reverse is true than the individual more than likely suffered from yaws.

To aid in the classification of treponemal disease based on the presence of caries sicca lesions on the skull Figure 23 can be used in order to establish the most likely cause of overall bone lesions given certain criteria. This flow chart should be used only to aid in classification and to give researchers a better idea of the disease that may have caused a specific set of bone lesions based on the lesions, age and climate zone. However, each set of remains must be treated independently and conclusions regarding the classification of treponemal disease based on the variety of factors that have been discussed thus far. In particular, when dealing with sub adult remains that fall outside of normal indicators for yaws or endemic syphilis, one must not make a classification of one specific treponemal infection, and consider other non-treponemal causes. Similarly when considering adult remains that exhibit caries sicca lesions, regardless of the climate one can never rule out venereal syphilis as a cause of the lesions, however, as indicated in the figure other treponemal causes may be more likely.

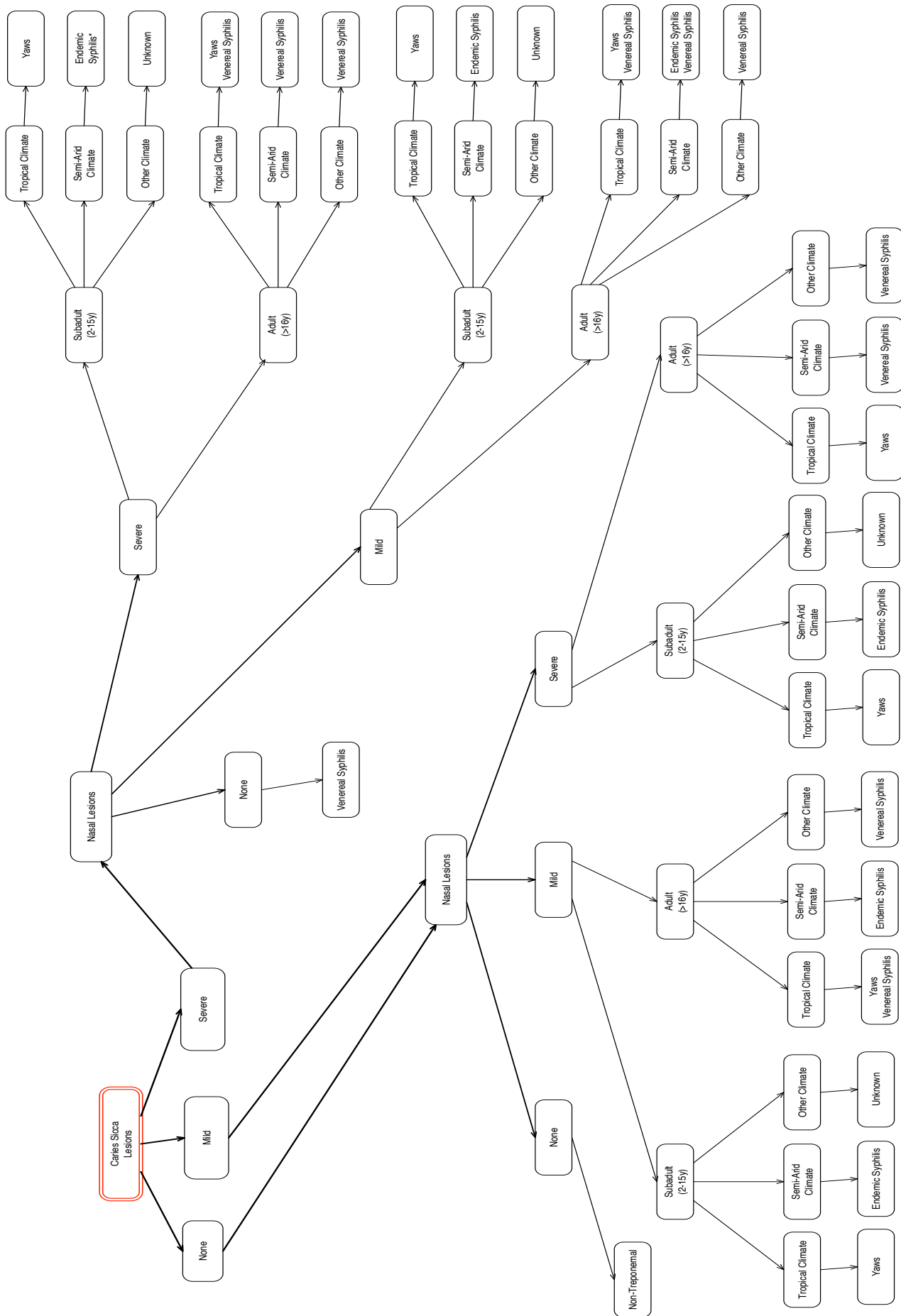


Figure 23: Classification and probable causes of caries sicca lesions on the human skeleton.  
 \*While a possible cause of lesions, other non-treponemal infections are more likely.

For example, in Buckley and Taves (2003) study of skeletal pathology in prehistoric pacific island samples, they observed that 26.8% of the observed crania in their sample exhibited cranial lesions including caries sicca. However, a higher proportion of crania of infants and young adults were affected than adult crania. In adults 19.5% of crania exhibited caries sicca lesions, however, there was an overall higher frequency of postcranial lesions (56.4%) compared to cranial lesions. Ultimately, after ruling out other non-treponemal disease, Buckle and Taves (2003) concluded that the lesions seen in their sample was likely due to yaws, not only because of the presence of characteristic yaws lesions but due to the fact that yaws was the most common treponemal disease affecting individuals in the pacific islands. This is the perfect example in which researchers have a sample that displays the cranial lesions that are more common in venereal syphilis compared to yaws. However, due to environment and that the fact that these lesions were seen more in children and young adults than adults the researchers ruled out other treponemal infections (endemic and venereal syphilis) in favor of yaws. A similar process can be used in order to classify venereal syphilis versus other treponemal infections.

If the skull is not present, or the frontal and parietal bones are missing from the sample, as other researchers have stated (Aufderheide and Rodriguez-Martin, 1998), it will be almost impossible to make a differentiation between treponemal disease. However, strides can be made based on the presence and severity of other lesions, as well as the age of the individual and the climate in which the bones originate. That being said, one should be careful classifying partial remains when key bones including the skull, tibia, radius and ulna are missing.

It is important to note that these conclusions only detail differentiating the skeletal lesions of treponemal infections of yaws and endemic syphilis from skeletal lesions of venereal syphilis. These classifications do not allow for the distinction of treponemal disease from other diseases,

such as leprosy, that may exhibit similar skeletal lesions to those seen in treponemal infections.

### **Significance of Research and Further Research**

While the prevalence of primary and secondary stage syphilis is increasing in modern times (Xu *et al.*, 2013), tertiary syphilis in terms of skeletal involvement has become rare as a result of the development and availability of antibiotics such as penicillin and the ability to identify syphilis and establish treatment practices in the early stages of infection (Weiss and Joseph, 1951; Xu *et al.*, 2013). Public health campaigns throughout the world set on eradicating the lesser treponemal diseases, such as yaws, have been largely successful (Binford and Connor, 1976). In the 1950's it was estimated that over 160 million people suffered from yaws throughout the world. Campaigns inoculating fifty million people with single doses of antibiotics resulted in a 95% reduction of yaws cases (reduced to approximately 2.5 million) (World Health Organization, 2014). However, campaigns aiming at eradicating treponemal diseases quickly lost priority, resulting in yaws infections still persisting in parts of the world, including areas of Africa and Asia (World Health Organization, 2014). While for modern societies Treponemal disease are no longer considered a priority due to the fact that they are easily treated with antibiotics, these disease are not eradicated. As a result, it is still possible to not only see these disease on the human skeleton in the archaeological record, but it is also possible for physicians to be presented with advanced cases of treponemal infections (particullary venereal syphilis) that have gone untreated. As Xu *et al.* (2013) point out, because of the rarity of tertiary stage syphilis in advanced societies, it is possible that physicians may not recognize the symptoms. Therefore, it is important to undertake studies such as this to determine the manifestations on the human skeleton show that they may be more easily identified.

Beyond modern medical practices, it is important to be able to identify venereal syphilis as compared to other treponemal infections in the archaeological record. For example, due to the fact that the only way to determine syphilis in archaeological skeletal remains is through significant study, it is theorized that the occurrences of venereal syphilis has been underestimated by up to 90% in the archaeological record (Roberts and Manchester, 2005). The ability to distinguish the cause of bone lesions in the archaeological record is significant because it will shed light on the diseases that populations may have suffered from, and can tell researchers more about the populations they are studying. Especially considering the social stigma that has been associated with venereal syphilis in the past, knowing whether or not a population suffered from venereal syphilis or other treponemal infections can shed light on day-to-day life for a population.

Finally, infectious diseases still remain one of the major causes of death worldwide. By studying infectious diseases of the past and their clinical manifestations, how they evolve, are transmitted and so on, researchers may shed light on infectious diseases, such as venereal syphilis, in the present (Roberts, 2000).

There is still more research to be done regarding treponemal infections. Specifically, into further distinguishing skeletal lesions on the human skeleton and to why treponemal infections target the long bones, cranial vault and nasal bones, over other areas of the skeleton. Furthermore, more research should be done in order to establish how other factors such as age, sex, immunologic susceptibility and nutrition affects how treponemal infections will impact the human skeleton, as all of these factors can impact how severe lesions may manifest on the human skeleton and how each treponemal infection presents pathologically.

## REFERENCES CITED

- Aufderheide AC, and Rodriguez-Martin C. 1998. The Cambridge encyclopedia of human paleopathology; including a dental chapter by Odin Langsjoen. Cambridge, UK: Cambridge University Press,.
- Binford CH, and Connor DH. 1976. Pathology of Tropical and Extraordinary Diseases. Washington DC: Armed Forces Institute of Pathology.
- Bollet AJ. 2004. Plagues & Poxes: The Impact of Human History on Epidemic Disease. New York: Demos.
- Buckley HR, and Tayles N. 2003. Skeletal pathology in a prehistoric Pacific Island sample: issues in lesion recording, quantification, and interpretation. American journal of physical anthropology 122(4):303.
- Collins DH. 1966. Pathology of Bone. London: Butterworths.
- Di Virgilio GA, Slosberg EJ, Serbin SF, Adickes ED, and Lavenda N. 1970. An Atlas of the evolutive life cycle of the human pathogen *Treponema pallidum*. Reading, Pa.: Reading, Pa., Rieck's Printing.
- Giacani L, and Lukehart SA. 2014. The endemic treponematoses. Clinical microbiology reviews 27(1):89.
- Hackett CJ.  
1951. Bone lesions of yaws in Uganda / by C.J. Hackett. Oxford: Oxford : Blackwell, 1951.  
  
1976. Diagnostic Criteria of Syphilis, Yaws and Treponarid (Treponematoses) and of Some other Diseases in Dry Bones. Sitzungsberichte der Heidelberger Akademie der Wissenschaften Mathematisch-naturwissenschaftliche Klasse. Berlin: Springer-Verlag.
- Hansen K, Hvid-Jacobsen K, Lindewald H, Sorensen PS, and Weismann K. 1984. Bone Lesions In Early Syphilis Detected By Bone Scintigraphy. Br J Vener Dis 60:265-268.
- Harper KN, Ocampo PS, Steiner BM, George RW, Silverman MS, Bolotin S, Pillay A, Saunders NJ, and Armelagos GJ. 2008. On the Origin of the Treponematoses: A Phylogenetic Approach PLoS neglected tropical diseases 2(1):148:141-113.
- Hoeprich PD, and Jordan MC. 1989. Infectious diseases : a modern treatise of infectious processes. Philadelphia: Philadelphia : Lippincott.

- Hudson EH. 1958. Non-venereal syphilis; a sociological and medical study of bejel. Edinburgh: Edinburgh, E. & S. Livingstone, 1958.
- Inhorn MC, and Brown PJ. 1997. Introduction. The Anthropology of Infectious Disease: International Health Perspectives. Australia: Gordon and Breach Publishers.
- Jaffe HL. 1972. Metabolic, degenerative, and inflammatory diseases of bones and joints [by] Henry L. Jaffe. Philadelphia: Philadelphia, Lea & Febiger.
- Mann RW, and Hunt DR. 2012. Photographic Regional Atlas of Bone Disease: A Guide to Pathological and Normal Variation in the Human Skeleton. Springfield: Charles C Thomas Publisher Ltd.
- Ortner DJ. 2003. Identification of Pathological Conditions in Human Skeletal Remains (2nd ed.). New York: Academic Press.
- Park KH, Lee MS, Hong IK, Sung JY, Choi SH, Park SO, Shin MJ, Chung HW, and Lee SH. 2014. Bone involvement in secondary syphilis: a case report and systematic review of the literature. Sexually transmitted diseases 41(9):532-537.
- Perine PL, Hopkins DR, Niemel PLA, John RKS, Causse G, and Antal GM. 1984. Handbook of endemic treponematoses : yaws, endemic syphilis, and pinta Geneva : Albany, NY: Geneva : World Health Organization.
- Radolf JD, and Lukehart SA. 2006. Pathogenic treponema : molecular and cellular biology Wymondham, Norfolk, England: Caister Academic.
- Roberts C. 2000. Infectious Disease in Biocultural Perspective: Past, Present and Future Work in Britain. In: Cox M, and Mays S, editors. Human Osteology in Archaeology and Forensic Science. London: Greenwich Medical Media. p 145-162.
- Roberts C, and Manchester K. 2005. The Archaeology of Disease. Ithica New York: Cornell University Press.
- Salt C, and Pye G. 2004. The syphilis enigma. Alexandria, VA: Distributed by PBS Home Video.
- Stirland AJ. 1991. Pre-Columbian Treponematoses in Mediaeval Britain. International Journal of Osteoarchaeology 1(1):39-47.
- Tremblay DL. 1996. Treponematoses in Pre-Spanish Western Micronesia. International Journal of Osteoarchaeology 6:397-402.
- Weiss RS, and Joseph HL. 1951. Syphilis. New York: Thomas Nelson & Sons.

- WHO. 2014. Yaws Strategy Development: Report of a Meeting. Atlanta GA: World Health Organization.
- Willcox RR. 1964. Textbook of venereal diseases and treponematoses / by R. R. Willcox. London: London : William Heinemann Medical Books, 1964.
- Wu SJ, Nguyen EQ, Nielsen TA, and Pellegrini AE. 2000. Nodular Tertiary Syphilis Mimicking Granuloma Annulare. *Journal of American Academy of Dermatology* 42(2):378-380.
- Xu X-G, Li Y-H, Gao X-H, Chen H-D, and Zhang Y-Q. 2013. A Case of Tertiary Neurosyphilis Presenting with Moth-Eaten Bone Lesions. *Dermatologic Therapy* 26:486-488.