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OCCURRENCE AND TRANSITIONS AMONG THE TREPONEMATOSES IN NORTH AMERICA

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Skeletal remains from the earliest identifiable North American populations were examined for evidence of yaws. These included the Windover, Ward, Carrier Mills, Frontenac Island, Lu°25, Oconto County, Palmer and Amaknak Island sites. Yaws-induced periostitis was noted in 27-40% of the skeletons, affecting both adults and subadults. The population frequency, subadult affliction frequency, polyostotic nature of disease, incompleteness of sabre shin remodeling, frequency of hand and foot involvement and absence of unilateral tibial disease were characteristic of yaws. Identification of yaws in the earliest North American populations supports the hypothesis that yaws walked with the first humans into North America.
There has clearly been a differential (geographic/time) transition of treponemal disease in the southwest. The patterns of disease reproducibly fulfill criteria for yaws (present initially), with subsequent recognition of syphilis. Syphilis appears to be a North American disease, which developed as a mutation from yaws approximately 2000 ybp on the Colorado Plateau. The time course of subsequent replacement of yaws by syphilis varies above and below the Mogollon Rim and appears compatible with timing of increasing social interactions between the groups.
Key words: Paleopathology, bejel, yaws, syphilis.

Restos óseos de las poblaciones mas tempranas de Norteamérica fueron examinados para evidencia de pián. La Periostitis inducida por pián fue identificada en un 27-40% de los esqueletos, afectando a adultos y subadultos. La frecuencia de la población, la afección de los subadultos,la naturaleza poliostotica de la enfermedad, la falta de reconstrucción completa de tibias en sable, la frecuencia de evidencia en las manos y los pies y la ausencia de enfermedad unilateral de la tibia eran características del pián. La identificación del pián en las poblaciones mas tempranas de Norteamerica apoya la hipótesis de que la enfermedad llego con los primeros humanos a Norteamerica. Claramente ha habido una transición diferencial (geográfica/temporal) de las treponematosis en el suroeste. Los patrones de la enfermedad cumplen y reproducen los criterios de pián (presente inicialmente) con el subsecuente remplazo por la sífilis. La sífilis parece ser una enfermedad que se desarrollo en norteamerica aproximadamente 2000 años aP en la Meseta de Colorado. El tiempo del subsecuente reemplazo parece ser compatible con el aumento de interacciones sociales entre los grupos.
Palabras claves: *Paleopatología, bejel, yaws, sífilis.*

Timing is fundamental to discussion of disease origins (Cockburn 1963). Analysis of timing, however, is dependent upon accurate diagnosis. The latter has been especially complicated for treponemal diseases (Baker and Armelagos 1988), because the only tests clinically helpful in distinguishing among the treponematoses are the history (of the illness, as related by the patient) and the physical examination. While laboratory tests may identify the possibility of a treponemal disorder, there are no histological, biochemical, immunologic or microbiologic techniques for distinguishing among them (Fieldsteel 1983; Noordhoek et al. 1990).

Treponemal disease is recognized on the basis of periosteal reaction and osteitis. The appearance of individual bones and the nature and intensity of bone damage are similar in all three varieties known to afflict skeletal structures (Hackett 1976; Rothschild and Rothschild 1995). However, the pattern of involvement is actually sufficiently disparate to allow distinguishing among them (Rothschild and Rothschild 1995, 1996; Rothschild et al. 1995a). Study of skeletal populations with Yaws (in pre-contact Guam), Bejel (in the 19th century Middle East) and syphilis (in 20th century Cleveland) allowed development of criteria, which have since proved reproducible in more than 40 archeologic populations (Rothschild and Heathcote 1993; Rothschild and Rothschild 1994, 1995; Rothschild et al. 1995a).

As the origins of Yaws in central Africa has been documented (Rothschild et al. 1995b), and as humans are a late Pleistocene/early Holocene addition to the North American fauna, it was of interest to understand treponemal disease interactions, timely to that migration.

Methods

The sample consists of skeletal remains from the collections of The American Museum of Natu-

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ral History (New York City), Florida State University (Tallahassee), Hamlin University (Milwaukee, Wisconsin), The Rochester State Museum (Rochester, New York), Southern Illinois University (Carbondale), and University of Alabama, Tuscaloosa, University of Florida (Gainesville), and University of Kentucky (Lexington). We visually examined all cortical surfaces to identify all osseous/ periosteal alterations throughout each skeleton. All variation from normal smooth cortical surfaces was noted. Treponemal disease was specifically recognized on the basis of periosteal reaction and osteitis (Freeman and Meschan 1943; Gann 1901; Goff 1967; Hackett 1976; Hunt and Johnson 1923; Moss and Biegelow 1922; Rothschild and Turnbull 1987; Rothschild and Heathcote 1993; Rothschild and Rothschild 1995).

Sites examined included Windover, Ward, Carrier Mills, Frontenac Island, Lu-25, Oconto Co., Palmer and Amaknak Island (Table 1). Amaknak Island is in the Bering Straits, the Ward site in Kentucky, Carrier Mills in Illinois, Frontenac Island in New York State, Lu-25 in Alabama, Oconto County in Wisconsin, and Windover in Florida. The latter represents the oldest known skeletal population from North America (Hauswirth et al. 1991).

The comparison sample for Yaws comprised 40 individuals from the Gognga Gun Beach Locale (Guam) dated at 500 years before present (Rothschild and Heathcote 1993). Yaws was the only treponemal disease present in Guam prior to 1668 (Heathcote 1991; Howells 1973; Rothschild and Rothschild 1995; Stewart and Spoehr 1952). The comparison sample for syphilis comprised one hundred and thirty five individuals selected from the 2906 skeleton Todd Collection (Cleveland) on the basis of autopsy diagnosis of syphilis (Rothschild and Rothschild 1995).

Six populations from the Colorado Plateau were examined. Ninety-one adult individuals from Kuaua (dated at 650-400 ybp), 89 from Pottery Mound (dated at 650-500 ybp), 27 from Mattock (dated at 1650-850 ybp), 40 Pueblo I Anasazi (dated at 1300-1100 ybp, 25 Basketmaker III (dated at 1500-1800 ypb), and 5 adult Basketmaker II from White Dog Cave (dated at 2000 ybp) (Cordell 1979; Emslie 1981; Gooding 1980; Plog 1979; Senter 1936; Woodbury and Zubrow 1979) were examined (Table 1). Skeletons from 4 sites, located south of the Mogollon Rim in Arizona were also examined. Eleven adults from Palo Pardo (dated at 1250-1450 ypb), 15 from the Chinchera site (dated at 1300-1100 byp), 173 from the Grasshopper site (dated at 1250-1450 ybp), and 139 individuals from the Turkey Creek site (dated at 1200-1400 ybp) (Emslie 1981; Gifford 1980; Gooding 1980; Longacre et al. 1982; Martin 1979; Senter 1936) were examined (Table 1). Fifty-six subadults from Colorado plateau sites more recent than 1800 ypb (Table 1) were examined and compared with six from the pre-1800 ybp site, 8 from the Mogollon sites older than 1100 ybp and 140 from more recent Mogollon sites.

The osseous reaction to treponemal infection, although reproducible for each variety, is not uniform among them (Rothschild and Rothschild 1995). Examination of population frequency, demography, character, and skeletal distribution of osseous treponemal impact provides clear, reproducible clues to the identity of the underlying treponemal infection (Rothschild and Rothschild 1995, 1996; Rothschild et al. 1995a). Yaws is a polyostotic (median number of bone groups affected = 4), high population frequency disorder (21-38%). It frequently affects the hands and feet and commonly produces bone lesions in subadults. Contrasted with the sabre shin reaction in syphilis, that in Yaws is invariably associated with surface evidence of periosteal reaction.

Results

Earliest populations Skeletal remains from 769 individuals were examined (Table 1). Site preservation was good, although hands and feet were missing from the Frontenac Island site and subadults were insufficiently represented at the Amaknak Island and Palmer sites.

Periostitis, diagnostic of Yaws, was identified in the Windover, Ward, Carrier Mills, Frontenac Island, Lu-25, Oconto Co., Palmer and Amaknak Island sites, as delineated in Table 1. Findings were identical to that previously noted in confirmed Yaws-affected populations and distinctive from those associated with syphilis.

Populations in Transition

Two clearly separable patterns of treponemal disease were noted. Anasazi who died less than 1800 years before present (ybp) and Mogollon who died less than 1100 ybp had a low population fre-

Table 1. Characteristics of Beiring Strait and Earliest American Treponemal Disease Contrasted with Documented Syphilis and Yaws

	Syphilis[1]	Yaws[1]	Windover	Ward	Carrier	Frontenac Mills	Amaknak Island	Lu-25 Island	Oconto WI
Site Age (years before present)[2]	70	500	7900	4300	6300	2000	2000	4300	3250
Population size - total	2906	40	112	203	159	63	16	89	37
Youth Affected > 5%	No	Yes	Yes	Yes	Yes	Yes	*	Yes	Yes
Sabre shin whithout periostitis	No	No	No	No	No	No	No	No	No
Unilateral tibial involvement	Yes	No	No	No	No	No	No	No	No
Average number of bone groups affected> or = to 3	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hand or foot commonly affected	No	Yes	Yes	Yes	Yes	**	Yes	Yes	Yes
Frequency perspectives Percent of a risk population affected	5%	33%	27%	36%	31%	38%	27%	40%	35%
Percent of youth affected	<1%	14%	12%	20%	16%	13%	*	17%	18%
Average number of bone groups affected	1.9	4.0	3.4	3.1	3.1	3.1	3.3	3.0	3.2

1 Derived from Rothschild and Heathcote (1993); Rothschild and Rothschild (1995)
2 Rothschil et al. (1992)
* Not present, but inadequate numbers (5 subadults) to rule out
** Hands and feet were absent from burials, precluding analysis

quency (<13%) of treponemal disease, pauci-ostotic (less than two bone groups affected) in distribution, with occasional unilateral tibial involvement, and sabre shin remodeling (Table 2). The latter was frequently so complete, as to efface all surface indications of periosteal reaction. The hands and feet were spared. This pattern was characteristic for syphilis and quite distinct from that noted for yaws and bejel (Hershkovitz et al. 1995; Rothschild and Heathcote 1993; Rothschild and Rothschild 1994a,b, 1995a,b; Rothschild et al. 1995). Consideration of subadult-sparing further substantiates this conclusion. Although numbers of subadults were limited in some sites, the overall sample (of this age/geographic composition) lacked a single example of subadult periosteal reaction (among 196 subadults).

Anasazi who died more 1800 ybp and Mogollon who died more than 1100 ybp had a very different pattern (Table 2). Both had high population frequency of periosteal reaction, with frequent subadult affliction [especially notable related to the relatively low number of juveniles available (13 individuals) for examination]. Disease was polyostotic. The extreme of distribution noted in the White Dog site is representative of the population variation expected in yaws (Rothschild and Heathcote 1993; Rothschild and Rothschild 1994a,b, 1995a,b; Rothschild et al. 1995). Hands and feet were frequently affected. Unilateral tibial involvement was not noted and sabre shin remodeling was always limited (such that surface periosteal reaction was always recognizable).

One approach to the "N of 1" White Dog Cave site is to combine data with that of the Chinchera site. That allows polyostotic disease to be reviewed as a more general population phenomenon (in populations documented on the basis of the other criteria as characteristic of yaws). The mean number of afflicted bone groups becomes 4 (from 3.5) and the median number of bone groups afflicted becomes 3.5 (from 3.0). Both sets of values are as

Table 2. The Time Cours and Path from Yaws (Centrally Displayed) to Syphilis (Laterally Displayed)
Above and Bellow The Mogollan Rim

	Anasazi						Mogollon					
Site	Syphilis	Kuaua	Pottery Mound	Houch Pueblo I	Windslow Bskmk III*	White Dog Cave	Yaws	Chinchera	Grass Hopper	Turkey Creek	Palo Pardo	Syphilis
Standard**/ Designation	Standard	LA187	LA416	AZ8968	AZ8038	AZ16-9A	**	EE9:53	P:14:1	W10:78	DD:8:12	**
Dating (YBP)		<650	<650	<1300	<1800	<2000		<1300	600-700	<800	<750	
Population frequency %	4-12	4	9	10	4	20	20-40	20	11	8	9	4-12
Number of bone groups > or = 3	No	No	No	No	No	Yes	Yes	Yes	No	No	No	No
Frequent Hand or Foot	No	No	No	No	No	Yes	Yes	Yes	No	No	No	No
Unilateral Tibia	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes
Totally Remodeled Sabre	Yes	Yes	Yes	Yes	***	No	No	No	Yes	Yes	***	Yes
Mean # of Bone Group	1.0-2.4	1.3	2.1	1.8	1.0	6.0	>3	3.5	1.9	1.3	2.0	1.0-2.4
Subadults > 5% Affected	No	No	No	No	No	Yes	Yes	Yes	No	No	No	No
Population Studied:												
# of Adults		91	89	40	25	5		15	173	139	11	
# of Subadults		14	36	3	3	6		8	89	47	4	

* Bskmk III = Basketmaker III

** Standards derived from Heathcote and Rothschild (1993); Rothschild and Rothschild (1994, 1995a,b); Rothschild et al. (1995)

*** Indicates not present, but small number precludes its exclusion has been previously documented in yaws (Rothschild and Heathcote 1993; Rothschild and Rothschild 1994a,b, 1995a,b; Rothschild et al. 1995).

The population frequency of treponemal disease for pre-1800 ybp sites was significantly greater (Fisher exact test, p =0.018) than that for subsequent Colorado plateau sites. The population frequency of treponemal disease in the pre-1100 ybp site was significantly greater (Chi square = 7.399, p < 0.008) than that for more recent sites below the Mogollon rim.

Discussion

Earliest populations Skeletal remains from Windover, Ward, Carrier Mills, Frontenac Island, Lu-25, Oconto Co., Palmer and Amaknak Island sites were compared with those with confirmed Yaws from the Gognga Gun Beach Locale of Guam (Table 1). Yaws-induced periostitis was noted in 27-40% of the skeletons from the sites examined in this study, indistinguishable from the 33% noted on Guam. Twelve to twenty percent of subadults were affected, compared with 14% on Guam. Periosteal striations with cortical thickening was noted. Periosteal new bone formation was occasionally associated with extensive gummatous destruction and cloaca formation, as was also noted in the skeletons from Guam.

The mean number of affected bone groups (e.g., tibiae were considered one bone group) ranged from 3.1 to 3.4 (Table 1), similar to that noted on Guam. Tibial involvement was most common (and invariably bilateral), followed in frequency by femur and fibula. Sabre shin deformity was always associated with irregular striated or thickened cortical surfaces. This contrasts with remodeling in syphilis sabre shins, often so substantial as to remove all surface signs of periosteal reaction (Rothschild and Rothschild 1995). The polyostotic disease in the studied sites contrasts with the pauci©ostotic nature of syphilis. The population frequency, subadult affliction frequency, frequency of hand and foot involvement and absence of unilateral tibial disease all contrast to what is observed in populations with syphilis (Rothschild and Rothschild 1995, Rothschild et al. 1995a).

Diagnosis (as to specific treponematosis) is based upon absence of "contradictory" findings and presence of supportative findings. All supportative findings are not required for diagnosis, but "contradictory" findings would eliminate a specific diagnosis from consideration. Presence of hands and feet in the Frontenac Island site population would provide additional information, but its absence does not alter the diagnostic perspective. So too, inadequate subadult representation does not compromise diagnosis of Yaws in the Amaknak Island and Palmer populations.

The osseous reactions, although reproducible for each variety of treponemal disease, are not uniform among them (Rothschild and Rothschild 1995). Examination of population frequency, demographics, character, and skeletal distribution of osseous treponemal impact provides clear, reproducible clues to the identity of the underlying treponematosis (Table 1). Yaws is more polyostotic and has a high population frequencies. Syphilis usually spares the hands and feet. Sabre shin remodeling in syphilis is more extensive than in Yaws. All surface evidence of periostitis may be lost in syphilis, whereas at least residua are detectable in Yaws.

While differential diagnosis of treponematoses includes venous stasis, hypertrophic osteoarthropathy (HOA), thyroid acropachy, hypervitaminosis A, fluorosis, and infantile cortical hyperostosis (Resnick and Niwayama 1988; Rothschild and Martin 1993), they are quite different in their manifestations. None cause sabre shin deformity. The distal diaphyseal distribution with epiphyseal extension in HOA is easily distinguished from the general diaphyseal, but epiphyseal-sparing lesions of treponemal disease. More generalized periosteal reaction in Yaws is at variance with the predominantly metacarpal, metatarsal, and phalangeal distribution of thyroid acropachy and the mandibular, clavicular, scapula and rib involvement of infantile cortical hyperostosis. Absence of enthesial (sites of tendon, ligament and capsular insertion) site calcification and lack of internal bone architecture distortion help to distinguish these findings from those of hypervitaminosis A and fluorosis. Diseases which are uncommon in the population should not occur with sufficient population frequency to compromise epidemiologic studies. Thus, the relative rarity of infantile cortical hyperostosis and thyroid acropachy would allow those diagnoses to be excluded, even were their skeletal distribution not sufficiently selective.

The history of treponemal disease in the New World can be definitely traced almost 8000 years. Evidence for treponemal disease in 2,500-3,000 year before present (bp) Siberian skeletons has been insufficient to ascertain the variety (Rokhlin and Rubasheva 1938). As remoteness of Siberian skeletal populations precluded facile analysis, the nature of treponemal disease along the pathway of migration (Bering Straits) and among Archaic North American populations seemed appropriate to pursue. On the basis of that analysis, it is suggested that Yaws migrated to the New World with the first Asian immigrants.

Populations in Transition

Two clearly separable patterns of treponemal disease were noted. A syphilis pattern was noted in Anasazi who died less than 1800 years before present (ybp) and Mogollon who died less than 1100 ybp (Hershkovitz et al. 1995; Rothschild and Heathcote 1993; Rothschild and Rothschild 1994a,b, 1995a,b; Rothschild et al. 1995). Anasazi who died more 1800 ybp and Mogollon who died more than 1100 ybp had a pattern typical of yaws (Rothschild and Heathcote 1993; Rothschild and Rothschild 1994a,b, 1995a,b; Rothschild et al. 1995). While both groups (Anasazi and Mogollon) experienced replacement of yaws by syphilis, the time course of replacement clearly differed.

Syphilis appears to be a North American disease, which transmuted from yaws approximately 2000 ybp on the Colorado plateau. The time course of mutation (disappearance of yaws and first observation of syphilis) appears to vary within the North American continent (Rothschild and Rothschild 1994a,b, 1995a; Rothschild et al. 1995).

While both groups (Anasazi and Mogollon) experienced replacement of yaws by syphilis, the time course of replacement clearly differed. While 1000 and 700 ybp have been suggested as transition times (Rothschild and Rothschild 1994b, 1995a; Rothschild et al. 1995) for the midwest and southern portions (respectively) of what is now the United States geographic area, the transition time (from yaws to syphilis) for the southwest appears slightly older below the Mogollon Rim and significantly older above it (on the Colorado plateau). While these conclusions have been deduced on the basis of actual population examination, repatriation has precluded similar evaluation of many of the desired west-central areas proximate to the Colorado plateau. Review of published literature on treponemal disease revealed several sites (Neuman 1975; Schermer et al. 1994) with sufficient documentation for application of criteria (for distinguishing among the treponematoses). Those sites still have the characteristics of yaws (Rothschild and Heathcote 1993; Rothschild and Rothschild 1994a,b, 1995a,b; Rothschild et al.. 1995) and suggest a transition time later than that noted on the Colorado plateau.

What happened in the southwest? Was there perhaps a highly contageous plague, which stimulated greater population segregation? Such might have led to cessation of sharing of eating utensils and food and separation in sleep. Such has been invoked in the form of the Black death as a possible explanation for the apparent pre-Columbian elimination of yaws in England. Such elimination of yaws would have established a virgin population (free of treponemal disease) for syphilitic infection. Black death or bubonic plague is also a southwestern (United States) phenomenon, occurrence of which could have represented a pivotal event in establishing susceptibility to a new treponemal (e.g., mutation) threat. Communicable disease concepts are clearly appropriate for consideration, as the timing of development of syphilis below the Mogollon rim appears to match that for development of significant interactions (Vivian 1990; Wasley 1960) between the Colorado Plateau and Mogollon peoples.

Differential (geographical) environmental alterations are also worth exploring (Baker and Armelagos 1988). The transition from Basketmaker II to Basketmaker III is characterized by increased sedentism and agrarianism (Vivian 1990). As weather shifts occurred slightly after the transition from Basketmaker II to III, they probably cannot be directly invoked as explanation for the transition of yaws to syphilis. The past 10,000 years have been relatively stable climatically in the southwest (Vivian 1990). Dean (1983) suggests there has been inadequate variation to stimulate cultural change. The area has been characterized by large diurnal and annual temperature variation in the range of 48 to 102 F. There appear to have been cyclic (550 year interval) 50 year periods of major drought (Dean et al. 1985; Euler et al. 1979). It is of interest that the transition periods (from yaws to syphilis) above and below the Mogollon rim both represented time of onset of one of those drought cycles.

There has clearly been a differential (geographic/time transition of treponemal disease in the southwest. The patterns of disease reproducibly fulfill the criteria for yaws (present initially), with subsequent recognition of syphilis. Now that the pattern has been exposed, perhaps cultural anthropologists, geographers, historians, and climatologists will share their insights and identify testable hypotheses which will allow us to more fully understand the transformation from yaws to syphilis.

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