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RESEARCH ARTICLE

Infectious diseases in North Eastern Argentina: Treponematosis and its connection with population concentration

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Abstract

This article presents cases of treponematosis in at least five individuals from different archeological sites in southern North Eastern Argentina and discusses how these cases were linked to the ways of life of the pre-Hispanic groups that inhabited this region for at least 2000 years. We carried out the reanalysis and reinterpretation of some of the pathological cases, including a comparison between our observations and previous diagnoses made by other authors. Thirty-three bone elements corresponding to a minimum number of five adults from three archeological sites were analyzed. These sites were excavated in the early and mid-20th century, and the archeological materials are currently under the guardianship of different museums. The macroscopic description of bone lesions was surveyed. The bone lesions in long bones, mainly saber shin appearance in tibiae, and one cranial vault are consistent with the development of treponematosis. This diagnosis in five individuals in the south of North Eastern Argentina adds to the two cases previously reported. The discussion is focused on the link between the presence of this pathology and the ethnohistorical, archeological, and environmental context of the studied area.

KEYWORDS
Argentina, museum collection, periodic floods, residential villages, treponematosis

1 | INTRODUCTION

Human skeletal remains housed at different museum collections in Argentina were surveyed as part of the systematic paleopathological investigation that we have been developing in North Eastern Argentina (NEA). Particularly, in this work we analyzed samples that were excavated in the early and mid-20th century and are currently curated in local museums, thus retrieving new information from these collections with new research questions and methodologies. As a result of these analyses, at least five individuals with lesions compatible with treponematosis were identified. This article presents these cases and discusses their relationship with the environmental characteristics and ways of life of the pre-Hispanic groups that inhabited this region. As part of the study, we reanalyzed and reinterpreted some of the pathological cases, which included contrasting our observations with previous diagnoses made by other authors.

Treponematosis is an infection caused by microorganisms of the genus *Treponema*. Four treponematoses are recognized: venereal syphilis (*T. pallidum pallidum*), endemic syphilis or nonvenereal syphilis (*T. pallidum endemicum*), yaws (*T. pallidum pertenue*), and pinta (*T. caretum*) (Ortner, 2008). The microorganisms usually enter the individual through the skin or mucous membranes causing a small skin lesion, which heals within the following weeks. After a latency period, in the secondary stage of infection, similar but widespread lesions appear in different parts of the body. The tertiary stage generally manifests several years later and is characterized by more severe and long-term injuries. At this stage, all syndromes except for pinta, can produce noticeable skeletal lesions (Farnsworth & Rosen, 2006; Hackett, 1976; Powell & Cook, 2005). Bone lesions are characterized as destructive

and proliferative and involve different bone elements. The bones most affected by treponematosis are the skull vault and bones of the forearm and lower leg (Ortner, 2008). The lesions in the skull were extensively studied and described by Hackett (1976), through the sequence of *caries sicca*. These cranial lesions consist in progressive involvement of the calvarium; it begins by round areas of clustered and confluent clustered pits in the outer table of the vault; the following stages are characterized by discrete series of focal superficial cavitation, circumvallate cavitation, and the formation of distinctive radial scars; this sequence ends with serpiginous and nodular cavitation (Hackett, 1976).

In the long bones, the changes are bone formation, destructive lesions, or a destructive focus surrounded by bone formation. In the tibia, bone formation occurs in the anterior crest, causing the bone to take a saber shin appearance (Hackett, 1976; Ortner, 2008; Powell & Cook, 2005). Although *caries sicca* has been mainly associated with venereal syphilis and considered pathognomonic (Hackett, 1976), it may also be diagnostic of endemic syphilis or yaws (Ortner, 2008), which are admittedly less frequent but morphologically identical. The saber shin appearance of the tibia is supportive mainly of the tertiary development of yaws (Farnsworth & Rosen, 2006; Powell & Cook, 2005), although this feature is frequently observed in venereal syphilis and endemic syphilis (e.g., Rothschild & Rothschild, 1995). However, beyond these differences in morphological expression, the only current solution for distinguishing between different types of treponematosis is the paleogenetic or paleogenomic approach (Guedes et al., 2018; Schuenemann et al., 2018).

The presence of treponematosis in pre-Hispanic groups in America has been documented for several years, particularly in North America where the extensive record of this pathology dates back at least 5000 years BP (Powell & Cook, 2005). In contrast, few cases of treponemal infections have been reported in southern South America (e.g., Allison, Focacci, Fount, & Cebelin, 1982; Aspillaga, Castro, Rodríguez, & Ocampo, 2006; Filippini, Pezo-Lanfranco, & Eggers, 2019; Standen & Arriaza, 2000). Particularly in Argentina, a few cases of pre-Hispanic skeletons with treponematosis were reported. Two of them come from the Patagonian region (Carsa and Cerro Yanquenao sites) and are linked to the late Holocene hunter-gatherer groups (Castro, Salceda, Plischuk, & Desántolo, 2009; García Guraieb, Bernal, González, Bosio, & Aguerre, 2009). Other individuals come from the archaeological site Doncellas in the northwestern region (1000–1450 AC; De Zela & Fuchs, 2019). In addition, six individuals with treponemal lesions in long bones were reported in San Félix archeological site, located in the central northwestern region (Drube, Salceda, & Martínez, 2011). Finally, two cases of treponematosis correspond to individuals from two archeological sites in the NEA: one from La Lechuza site (Cornero & Puche, 2007) and the other from Los Tres Cerros 1 site (Ramos van Raap & Scabuzzo, 2018a).

2 | SAMPLE AND METHODS

In this work, 33 bones corresponding to a minimum number of five individuals were analyzed. These human remains from adults were recovered from the following three sites located in the south of the NEA: Túmulo I and Túmulo II del Brazo Largo, located in the Lower Delta of the Paraná River, and San Luis Médanos, located on the right bank of the lower basin of the Uruguay River (Figure 1, Table 1). These sites were excavated in the early and mid-20th century and archeological materials are currently under the guardianship of different museums.

The Túmulo I del Brazo Largo site (TIBL; Figure 1) was excavated in 1906 by researcher Luis María Torres, as part of the investigations sponsored by Museo de La Plata (MLP; La Plata, Buenos Aires, Argentina). This site is an elevation of anthropic origin with numerous human burials and archeological materials (Torres, 1911). Human burials are currently under the supervision of the MLP, and there is no explicit information about the number of individuals or the burial modalities. Torres (1911) performed a detailed analysis of the bone assemblages of TIBL and reported the finding of a male adult skeleton with bone lesions in the cranial vault and several long bones. Specifically, he describes the alteration in the diaphysis of the tibiae, characterized as "bowed forward." Photographs of these bones were published by Torres, who attributed the injuries to a "possible hereditary syphilitic infection" (Torres, 1911, p. 378). When we consulted the osteological collection of this site, some bones corresponding to this individual were found (TIBL-118) as follows: the skull (incomplete, with facial region missing), the jaw, and 16 postcranial bones (Table 1). These bone elements were reanalyzed and presented in this work (Table 1). A radiocarbon dating of 656 ± 42 years uncal BP was obtained (544–657 years cal BP) from one of the skeletons in this site (Bonomo, Politis, & Gianotti, 2011).

Túmulo II del Brazo Largo (TIIBL; Figure 1) was excavated in 1923 by Octavio Fernández (Division Assistant at MLP) and Pablo Gaggero (then a student at Instituto del Museo de la Universidad Nacional de La Plata, Argentina). Archeological materials and human bones were found at this mound site and are currently under the supervision of the MLP. In his report, Gaggero (1923) describes the finding of numerous skulls and postcranial bones. According to the data and photos, the individuals may have been buried in secondary burials. Although Gaggero could not associate the long bones with their corresponding skull to identify the individuals, he mentions the presence of "various pathological bones" that would belong to the same individual (Gaggero, 1923, p. 4). When consulting the osteological collections, we identified a total of 14 pathological bones corresponding to at least three adult individuals (Table 1). These bones have different catalog numbers and the explicit criteria by which the elements were grouped and inventoried are unknown. Since such numbers do not correspond to skeleton or burial, we decided to consider all the bones an assemblage. A radiocarbon dating of 756 ± 46 years uncal BP (627–728 year cal BP) was obtained from one of the skeletons in this site (Politis et al., 2017).

San Luis Médanos (SLM; Figure 1) was discovered and studied by Manuel S. Almeida during the second half of the 20th century, within the framework of his archeological work carried out in the city of Gualeguaychú (Entre Ríos province). Due to the lack of information about the site and the fact that the area was modified by extraction, it

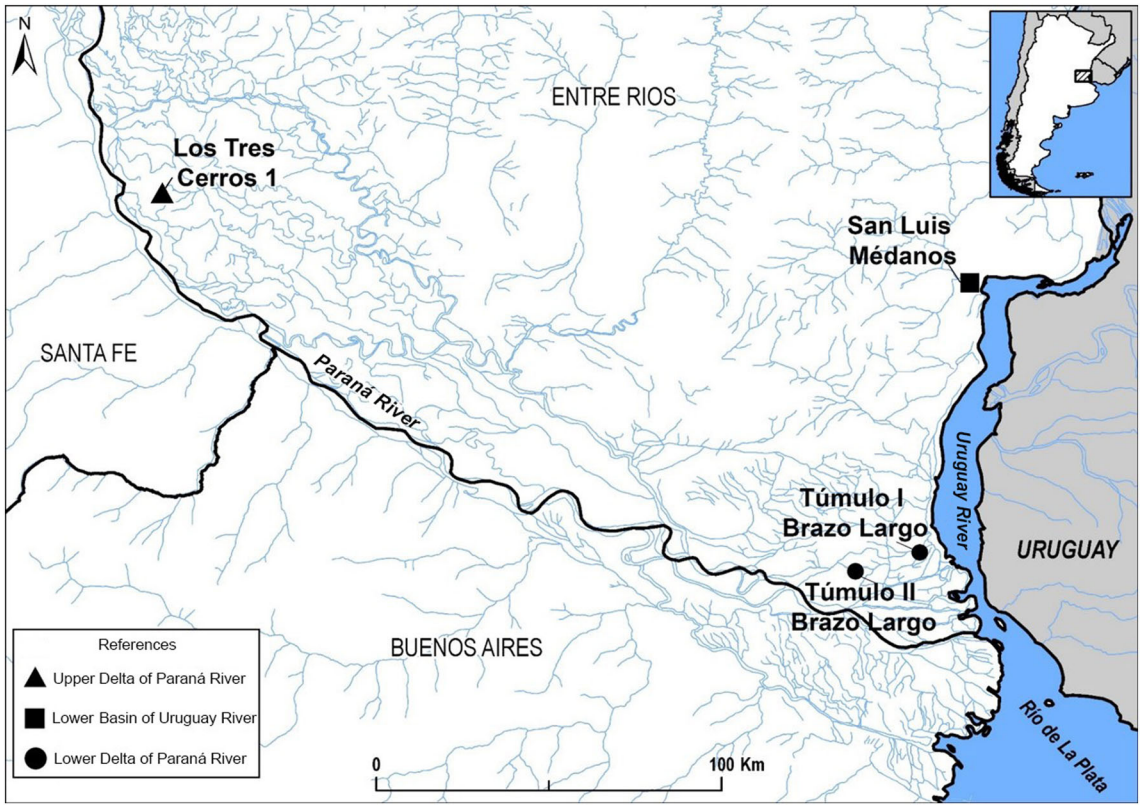

FIGURE 1 Location of the archeological sites mentioned in the text

TABLE 1 Information about the individuals analyzed

Region	Archeological site	Individual/bone number	Age	Sex	Bones analyzed	Date (^{14}C BP)	Reference
Lower Delta of Paraná River	Túmulo I del Brazo Largo	TIBL-118	Adult	M	*Skull*, mandible, scapulas, *left clavicle*, *sternum*, *humerus (right)*, *radius (left)*, ulnas, femurs, *tibiae*, *fibulae*	656 ± 42 *	Torres (1911), Bonomo, Politis and Gianotti (2011)
	Túmulo II del Brazo Largo[a]	6072 and 6071	Adult	Indet	*tibiae*, *left fibula*	756 ± 46 *	Gaggero (1923), Politis et al. (2017)
		6071	Adult	Indet	*right tibia*, *right fibula*		
		6073	Adult	Indet	*Left tibia*		
Lower basin of Uruguay River	San Luis Médanos	SLM-65	Adult	Indet	*Cranial vault*	n/d	Castro and Del (2015), Ramos van Raap and Scabuzzo (2018b)

Note. Words in italics corresponds to the bones with lesions.
Abbreviations: M: male; n/d: no data.
References: *Radiocarbon dating of human remains from a burial found in the site.
[a]For this site other bone injuries were also analyzed, but they could not be associated with any of the individuals identified.

is unknown whether SLM corresponds to a mound or not (Castro & Del Papa, 2015). In addition to archeological materials, human bones were found at the site (Ramos van Raap & Scabuzzo, 2018b). Two inventory numbers from SLM are mentioned in the Catalog of Human Remains of the Museo de Ciencias Naturales y Arqueología Profesor Manuel Almeida (Gualeguaychú, Entre Ríos province). Only skull fragments are mentioned under both catalog numbers. In the analyses carried out in this collection, only one of the cranial vaults was found. This corresponds to an undetermined adult (Table 1) with pathological lesions, which were analyzed in this study. No radiocarbon datings are available for the site.

The sex of the individuals was determined from the morphological characteristics of the skull (Buikstra & Ubelaker, 1994). The age at death was estimated from the fusion of the bone epiphyses

(Buikstra & Ubelaker, 1994). Specifically, for the bone assemblage from TIIBL the minimum number of individuals represented was quantified according to the bone elements present and their laterality (Lyman, 1994). Likewise, antimeric bones and anatomically adjacent bones were reassembled. This methodology involved the morphological and/or metric comparison of the bone elements (Todd & Frison, 1992). The bone lesions were studied by naked-eye macroscopic examination of the cortical surface and with a 10× stereomicroscope. Different characteristics were observed and recorded: bone and side; affected section (proximal and distal epiphysis, proximal and distal metaphysis, and proximal, medial, and distal diaphyses); affected surface (anterior, posterior, medial, and lateral); type of bone (primary, secondary). Photographs of the bone lesions were also taken.

3 | RESULTS

3.1 | Túmulo I del Brazo Largo site

The reanalysis of the incomplete skeleton of the TIBL-118 individual, specifically the skull, confirmed the age and sex determination (male adult) previously carried out by Torres (1911). Among the surveyed bones, bone lesions are detected in the skull, left clavicle, right humerus, sternum, left radius, tibiae, and fibulae (Table 1).

In the skull, bone lesions are observed in the center and the left portion of the frontal as well as in the right parietal extending to the occipital. In the frontal bone, areas with an irregular appearance and slight depressions are observed. In the center of the frontal bone, the surface changes are more expansive (Figure 2a) whereas in the left portion, a local expression with nonactive bone is noted (Figure 2b). The right parietal exhibits superficial cavities without signs of bone remodeling on its edges (Figure 2c). Regarding the injuries recorded in the postcranium, the long bones, the clavicle, and the sternum present periosteal reactions with primary and secondary bone deposits. The clavicle shows slight porosities resulting from the reactive bone (Figure 2d). The posterior surface of the sternum also shows some bone destruction due to taphonomic factors (Figure 2e). The posterior surface of the distal diaphysis of the right humerus exhibits periosteal reaction with superficial porosities (Figure 3a,b); the lateral surface of the distal diaphysis, displays a possible striated node with central cavitation (Hackett, 1976, p. 93–97; Figure 3c). None of the bones have compromised joint surfaces. The distal end in the left radius presents superficial porosities and a slight modification of the morphology due to the accumulation of the periosteal bone (Figure 3d,e). A possible striade node with central cavitation is also observed on the medial surface (Figure 3f). The distal articular surface is absent due to taphonomic damage. The fibulas present focalized periosteal reaction on the medial surface of the distal diaphysis. Interestingly, the tibiae were

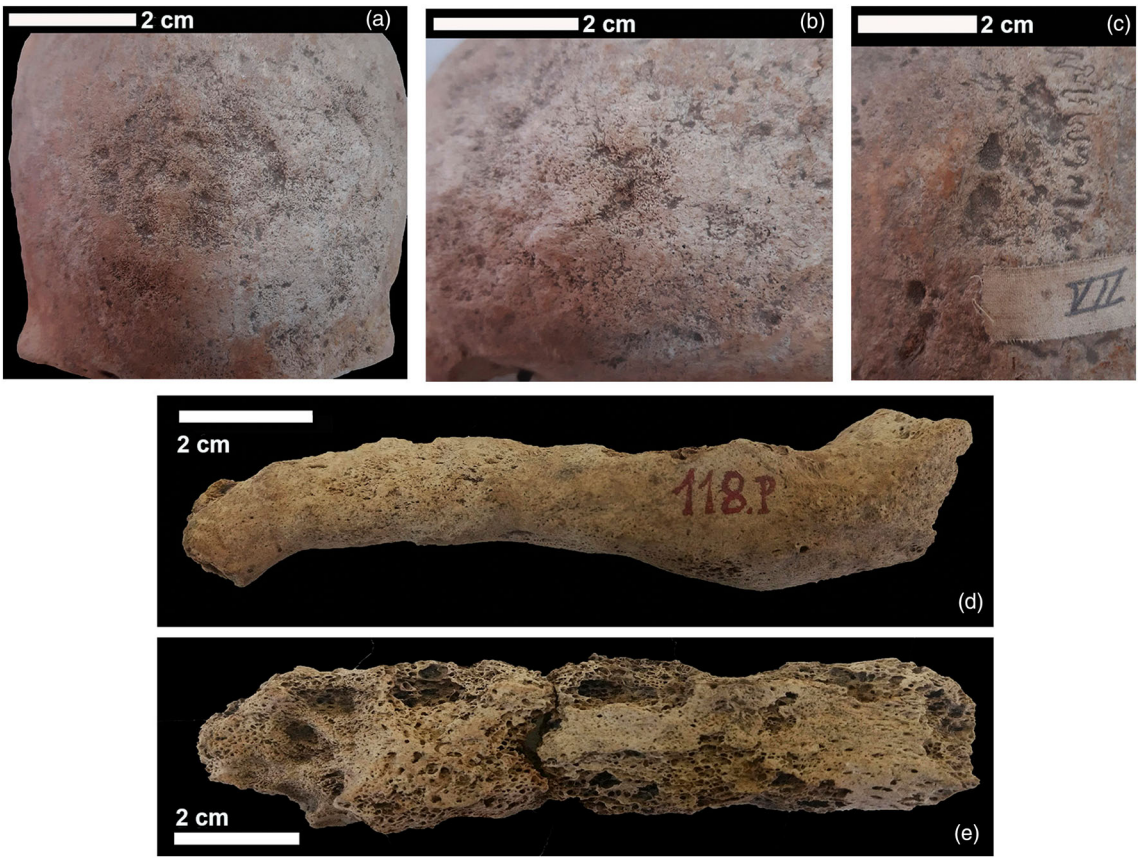

FIGURE 2 Bone lesions in individual TIBL-118 from Túmulo I del Brazo Largo site; (a) frontal, central region; (b) frontal, left region; (c) right parietal; (d) left clavicle; (e) sternum, posterior surface

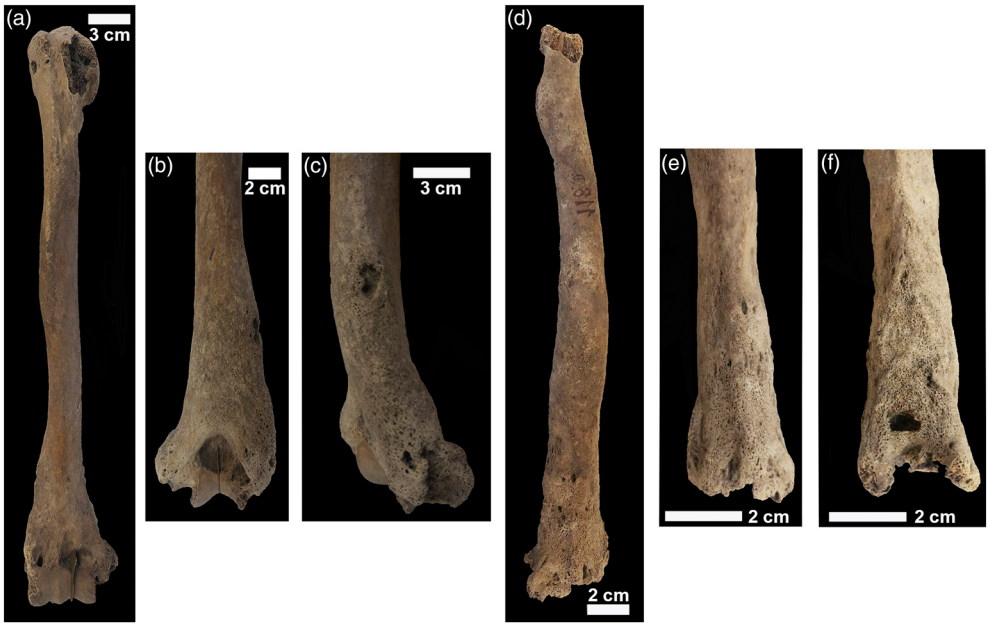

FIGURE 3 Bone lesions in individual TIBL-118 from Túmulo I del Brazo Largo site; (a) right humerus; (b) right humerus, posterior surface of the distal diaphysis; (c) right humerus, lateral surface of the distal diaphysis; (d) left radius; (e) left radius, lateral surface of the distal diaphysis; (f) left radius, medial surface of the distal diaphysis

modified during their storage in the museum. A partial cross section in the right tibia and a total longitudinal cut were made in the left tibia (Figure 4). This allowed us to observe the bone marrow cavity without the need for tomography or radiography. In both tibiae, a medullary cavity obstruction was recorded due to successive episodes of subperiosteal bone deposition mainly in the anterior crest. As a result, the whole tibial shaft appears swollen and with anterior bowing. This is observed clearly in the left tibia (Figure 4c), which also presents some new bone deposition on the posterior surface of the diaphysis.

FIGURE 4 Bone lesions in individual TIBL-118 from Túmulo I del Brazo Largo site; (a) right tibia with partial cross-section cut; (b) left tibia; (c) total longitudinal cut of left tibia

3.2 | Túmulo II del Brazo Largo site

For the TIIBL site, Gaggero (1923) mentions the finding of pathological bones that he assumes belong to the same individual. However, the analysis of the 14 bones of the MLP osteological collection and the anatomical reassembly of some bones indicated that the pathological elements correspond to a minimal number of three individuals. All the bones correspond to adult individuals according to the complete epiphyseal fusion. Due to the absence of diagnostic parts, sex determinations could not be made.

One of the analyzed individuals (6071–6072; Table 1) is represented by both tibiae and the left fibula. The right tibia shows periosteal reactions on different sides of the diaphysis. It is also possible to observe the alteration of the morphology with anterior bowing (Figure 5a). Likewise, two possible striated nodes with central cavitation (Hackett, 1976, p. 93–97) are observed on the anterior and posterior surface of the medial and distal diaphysis (Figure 5b). The left tibia exhibits modified morphology although it does not show the remarkable bowing appearance of its contralateral. It also presents active periosteal reactions and possible striated nodes with central cavitation. In addition, possible striated nodes and active bone reactions are observed in the left fibula. The distal diaphysis shows modified morphology with an increased outer diameter (Figure 5c).

Another individual in this collection is represented by the right tibia and right fibula (6071; Table 1). The tibia presents anterior bowing (Figure 5d). It exhibits active periosteal reactions mainly on the lateral surface of the diaphysis. In the fibula, we observed modified

FIGURE 5 Bone lesions in individuals from Túmulo II del Brazo largo site; individual 6071–6072: (a) right tibia; (b) striated nodes on posterior surface; (c) left fibula; (d) right tibia (individual 6071); (e and f) left tibia and cross-section cut (individual 6073)

morphology in the middle of the diaphysis and formation of secondary bone tissue.

The third individual was determined from a left tibia (6073; Table 1), which also shows anterior bowing. Like the tibiae of TIBL-118, it was modified during storage in the museum and it exhibits a total cross-section cut (Figure 5e). This cut made it possible to observe the complete obliteration of the bone marrow cavity due to successive episodes of subperiosteal bone deposition (Figure 5f).

Finally, the remaining eight reanalyzed bones with bone lesions could not be associated with any of the three individuals mentioned. Nevertheless, we do not exclude a possible association with one of them. On the one hand, a right clavicle and a left clavicle were identified as likely corresponding to the same individual, according to the anatomical reassembly. Both clavicles have active periosteal reactions. The left clavicle shows modified morphology and lytic processes on both sides, which seem to be superficial (Figure 6a). On the other hand, a left humerus, a left radius, and both ulnae were analyzed, and the anatomical reassembly revealed that these bones belong to the same individual. The four elements present modified morphology due to the accumulations of periosteal new bone. Likewise, the left ulna (Figure 6b) and left radius (Figure 6c) have possible striated nodes on their posterior surfaces. Another left radius presents the modified morphology in its distal half with a greater presence of secondary bone tissue. Finally, an incomplete right tibia with a current transverse fracture in the proximal third was analyzed (Figure 6d). Episodes of superiosteal bone deposition on the tibial crest and a reduced medullary cavity can be observed (Figure 6e).

3.3 | San Luis Médanos site

The SLM-65 skeleton corresponds to an adult, of undetermined sex, and it is represented only by the cranial vault (both parietal and occipital). This incomplete skull presents taphonomical alterations such as bone breakage and calcifications on the surface. In the right parietal, an area with necrotic bone was recorded in the sector extending to the frontal bone (Figure 7a). The ectocranial lesion extends into the diploe, showing an irregular appearance in the cross section, without affecting the internal table. The same feature was recorded in part of the left parietal but not as clearly (Figure 7b). Finally, a layer of sclerotic bone was recorded on the right parietal extending to the occipital (Figure 7c).

4 | DISCUSSION

In this study, the bone lesions of at least five individuals from southern NEA were described. These lesions revealed some aspects for the diagnosis of such bone conditions, which are highlighted below.

In the TIBL-118 individual, lesions in the cranial vault and postcranial bones were recorded. In the postcranial bones, periosteal reactions were observed with the presence of cavitations and a possible striated node with central cavitation in the humerus, such as those recorded by Hackett in individuals with treponematosis (Hackett, 1976, p. 93–97). Particularly in both tibiae, the anterior

FIGURE 6 Bone lesions from Túmulo II del Brazo Largo site; (a) left clavicle; (b) left ulna; (c) left radius, distal diaphysis; (d) right tibia; (e) right tibia with a transverse fracture

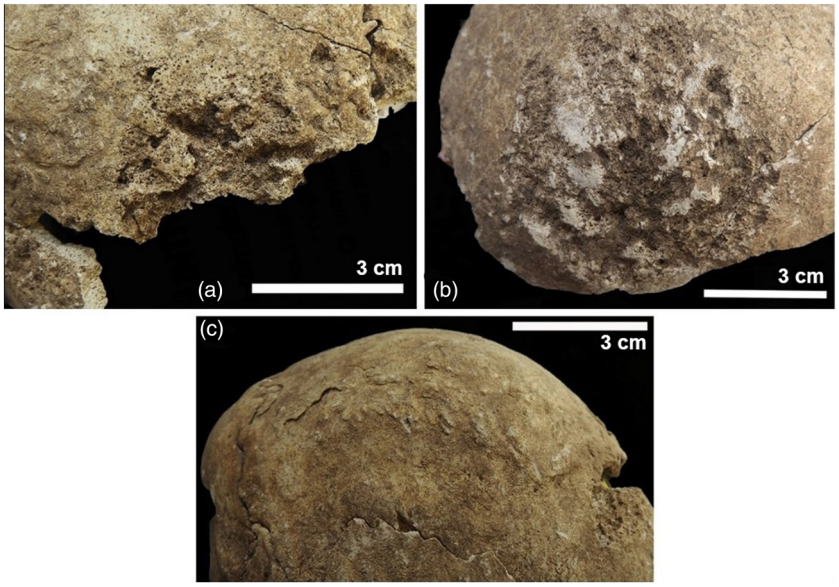

FIGURE 7 Injuries in the cranial vault of SLM-65: (a) right parietal bone extending to the frontal; (b) left parietal bone extending to the occipital; (c) right parietal bone extending to the occipital

bowing is noted due to successive episodes of subperiosteal bone deposition in the anterior crest. This curved appearance is called saber shin and it is known to be pathognomonic of treponematosis (Hackett, 1976; Ortner, 2008; Powell & Cook, 2005). Regarding the skull, the lesions recorded on the frontal and parietal regions are clearly not the typical changes that could be observed in the sequence of *caries sicca*, like circumvallate cavitation, radial scars, or serpiginous cavitation. However, the different affected postcranial bones, the periosteal nature of the reactions, and the bowed appearance of the anterior tibiae in this individual are suggestive of treponemal infection. As previously mentioned, the analysis of the same bones made by Torres (1911) led him to diagnose such injuries as "hereditary venereal syphilis." Our diagnosis does not agree with Torres's proposal because no effective distinction can be made between venereal and nonvenereal forms of treponematosis on the single basis of their individual skeletal lesions.

Five tibiae and two fibulas of at least three adults from TIIBL site were recorded. All the tibiae present periosteal reaction and anterior bowing (saber shin), and two of them exhibit striated nodes with central cavitation (Hackett, 1976). These lesions support a diagnosis of treponemal infection. In addition, isolated long bones with injuries showed severe periosteal reactions and some nodes on clavicles,

humerus, radius, and ulnas shafts. These injuries could correspond to the same diagnosis of treponematosis.

Finally, the individual from SLM site is the least conclusive case because it is an isolated and incomplete cranial vault with taphonomical alterations. However, the necrotic area in the skull vault presents the appearance known as "worm-eaten" (El-Najjar, 1979). Several researchers described this aspect as characteristic of treponematosis (El-Najjar, 1979; Hackett, 1976; Steinbock, 1976). Although some authors have linked this type of head lesion with venereal syphilis (El-Najjar, 1979; Steinbock, 1976), in this case study with a single bone element, it is premature to attribute the injuries observed to this treponemal syndrome.

In addition to these five individuals with the diagnosis of treponematosis, there could be another case for the southern NEA. It was recovered from Túmulo I del Paraná Guazú site by Torres (1911), who presented a photograph of the skull of a female adult and described the injuries observed in the cranial vault (Torres, 1911, p. 131). In the caption of the published photograph, Torres suggests that the conditions may correspond to "gummatous osteomyelitis of the cranial vault; infectious deploitis?" (Torres, 1911, p. 130). Judging from the necrotic appearance of the vault described and from the only available photograph, the case resembles those reported for treponemal pathologies by various researchers (e.g., El-Najjar, 1979; Hackett, 1976); it is also consistent with the active destructive injuries of the SLM-65 skull presented here. Beyond the descriptions made by Torres at the beginning of the 20th century, these skeletons could not be reexamined to confirm the diagnosis.

Although it is necessary to carry out paleogenetic or paleogenomic analysis to distinguish between venereal and nonvenereal forms of treponematosis, it is interesting to discuss whether the cases presented in this paper may correspond to the nonvenereal treponematosis. The most intriguing aspect is the link of this infectious pathology with the environmental conditions and ways of life of the pre-Hispanic populations that inhabited the southern NEA 2000 years ago. In general, social factors such as poor community hygiene have been associated with the presence of nonvenereal treponematosis (Csonka & Pace, 1985; Hackett, 1976). Likewise, more recent studies conducted in different pre-Hispanic bioarcheological groups in the United States postulated its association with sedentarism and population aggregation (Hutchinson, Larsen, Williamson, Green-Clow, & Powell, 2005; Powell, Jacobi, Danforth, & Eisenberg, 2005; Smith & Betsinger, 2015). The warm and humid climate that characterizes the subtropical regions also favored the development of treponemal lesions, as observed in South Florida (Hutchinson, Larsen, Williamson, Green-Clow, & Powell, 2005, p. 108). In addition to population aggregation and climatic conditions, other factors may affect the expression of treponematosis. These include body contact, personal hygiene, the virulence of the disease, the nature of palliative care, and individual fragility (Smith & Betsinger, 2015, p. 862).

In considering the information summarized above, it is important to contextualize the cases of treponematosis reported in this work within the particular archeological and environmental conditions of the area under study. In this sense, according to the 16th-century ethnohistorical sources (e.g., Fernández de Oviedo & Valdés, [1547] 1851, 1851–1855; Ramírez, [1528] 1902 in Madero, 1902; Schmidel, [1567] 2009), the indigenous people that inhabited this region lived on the riverbanks. Their "villages" had squares where they built large huts with sticks and straw wicker. It is also likely that they lived in large communal dwellings (Bonomo et al., 2019, p. 595). Pero Lopes de Sousa's diary also mentions the existence of large population settlements. This document provides detailed information about his trip throughout the Río de La Plata and the Lower Delta of Paraná in 1531. This Portuguese explorer observed a set of dwellings that formed a large settlement along the coast, which was occupied by between 500 and 600 people for almost a month (Politis, 2014). Thus, the existence of permanent or semipermanent villages can be inferred from the analysis of the diary and this particular reference. The descriptions of Lopes de Sousa could also be interpreted as residential settlements possibly related to the Chaná-Timbú (Politis, 2014). The ethnic groups that inhabited the region at the time of the conquest are associated with Goya-Malabrigo archeological entity. The living spaces occupied by this archeological entity for long periods were the anthropic mounds, which also functioned as semipermanent villages (Politis & Bonomo, 2012).

In addition, the hydrometeorological susceptibility that characterizes the areas under study is another factor to be considered (Castiñeira Latorre et al., 2017). The Paraná Delta has a humid climate with abundant rainfall. It is a complex water network formed by rivers, streams, lagoons, and swamps. It is affected by periodic floods that cover a large area of the land for extended periods. These environmental characteristics favored the concentration of people in the highest areas of the landscape (Castiñeira Latorre et al., 2017). Together, these data suggest some stability of occupation in the same residential settlements. Likewise, during these flood periods, animals, such as small rodents that can transmit various infectious diseases, would also concentrate in high places not covered by water (Politis & Bonomo, 2012). These periods, distinguished by population aggregation, may have generated an increase in the incidence of infectious diseases of direct transmission and/or associated with poor hygiene and health conditions. These situations may have favored the development of nonvenereal treponematosis. In this sense, the individuals analyzed in this paper come from monticular sites where people concentrated for long periods of time, especially during floods. Besides, it should be noted that other infectious diseases (e.g., osteomyelitis) were reported by different researchers in this area of study (Kozameh & Brunás, 2009; Ramos van Raap, 2018; Torres, 1911).

Although exposure to different infectious microorganisms would have been recurrent at times of population nucleation, the bioarcheological analyses indicate that few individuals show signs of treponematosis in southern NEA. Therefore, we must consider that the skeleton is affected only in the third phase of the disease process, suggesting that more individuals may have suffered from treponematosis without reaching the stage of bone symptoms (Wood, Millner, Harpending, & Weiss, 1992). In future studies, we will deepen the diagnosis of skeletons with nonspecific bone reactions in multiple bone elements and assess their link with treponematosis.

5 | CONCLUSIONS

Few cases of treponemal disease were recorded in Argentina's bioarcheological collections of pre-Hispanic populations. The present study provides new evidence of treponematosis in the North Eastern region. As a result of the five cases reported in this study, the treponematosis record in the study area has increased exponentially. According to the available chronologies, it should be noted that the presence of treponematosis in this area is temporarily limited to a period of 160 years, between 801 and 656 years BP.

Based on the diagnosis of treponematosis of these individuals and their ethnohistorical, archeological, and environmental contextualization, we propose that the presence of this infection is mainly linked to the ways of life of these populations, specifically with the population concentration in semipermanent residential settlements (villages). Furthermore, these settlements, located in high areas of the landscape, were inhabited during long flood periods. Although the reported cases are scant, this is not understood as a product of low incidence in contracting the disease. We propose that more individuals may have been affected by treponematosis, without their bones being compromised. In the short term, our research will further focus on this line of study to identify more cases of treponematosis in these latitudes.

Finally, it is important and crucial to emphasize that the osteological collections studied in this paper have been preserved in different institutions, in some cases for more than 100 years. Therefore, today it is possible to study these samples with modern methods and techniques and to integrate them into the current archaeological problems.

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DATA AVAIABILITY STATEMENT

The authors confirm that the data supporting the findings of the study reported herein are available within the article.

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