

Oral stress and paleodiet changes among hunter-gatherers from Negro River (northern Patagonia, Argentina) during the late Holocene

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Abstract

The objective of this work is to evaluate temporal variation of dento-alveolar lesions in hunter-gatherer groups who inhabited the middle course of the Negro River during the late Holocene (ca. 3000–750 years BP) in order to discuss cultural practices and changes in the paleodiet. Caries, dental calculus, periodontal disease, periapical lesions, *antemortem* tooth loss, tooth wear, dislocation, and osteoarthrosic lesions in the temporomandibular joint were analysed. The sample is represented by 567 teeth and 547 alveoli, corresponding to 32 adult and subadult individuals, who were divided into two periods for comparative purposes: pre-1000 and post-1000 BP. The results indicate a low prevalence of oral lesions without differences between sex and age. In the pre-1000 BP period, there is a larger frequency of *antemortem* tooth loss, parafunctional wear of the anterior teeth, dental dislocations, and osteoarthrosis in the mandibular condyles compared with the post-1000 period. This tendency indicates that the individuals would have been exposed to greater stress in chewing. However, the variations were not significant, so there is no clear evidence of changes in the diet and particularly in carbohydrate and plant intake through the late Holocene. Severe tooth wear is the main factor that caused some pathologies (e.g., *antemortem* tooth loss), and limited the development of others (e.g., caries). The results obtained here agree with other microregions from northeastern Patagonia and differ from Humid Pampas, eastern Pampa-Patagonian transition, and lower course of the Negro River due to differences in carbohydrate consumption in the last ca. 1000 years BP.

KEYWORDS

antemortem tooth loss, dental wear, hunter-gatherers, late Holocene, wild plant

1 | INTRODUCTION

The inland hunter-gatherers of the Patagonian region (Argentina) have been traditionally associated with a protein-based diet obtained mainly through big game hunting. From the final Pleistocene to the 15th century, subsistence and economy were primarily based on the exploitation of guanaco (*Lama guanicoe*; Mengoni, 1999; Miotti & Salemme,

2004; Cordero, 2012; Miotti, 2012). Beyond this general pattern, paleodiet shifts were observed during the late Holocene in different microregions, which were mainly associated to environmental and demographic constraints, and also to technological changes (Cordero, 2012; Gómez Otero, 2007; Martínez, 2017; Zangrando, 2009). In northeastern Patagonia, although significant archaeological changes have been proposed to occur around 1500–1000 years BP, these

changes seem to have varied over microregions (Figure 1). For the northern coast of the San Matías Gulf, it has been proposed predominantly marine diets of high trophic level between ca. 3100 and 2200 years BP, and mixed to terrestrial diets between ca. 1500 and 420 years BP, through stable isotopes (Favier Dubois, Borella, & Tykot, 2009). Zooarchaeological studies indicated exploitation of marine resources between 3000 and 2000 years BP, a greater increase of terrestrial vertebrates during ca. 2000–1000 years BP and a marked increase in the use of major continental vertebrates after ca. 1000 years AP (Marani, 2016). In the lower valley of the Colorado River, zooarchaeological studies indicate subsistence based on the consumption of guanaco, deer, and rhea sp. between ca. 3000 and 1000 years BP. Then, during ca. 1000–250 years BP, subsistence transformations occurred related to a process of intensification in the exploitation of some resources (e.g., guanaco) and the diversification in the consumption of different prey of medium and small sizes (e.g., fluvial and marine fish and armadillo; Stoessel & Alcaráz, 2017). Stable isotopes in human remains confirmed this trend in the paleodiet of hunter-gatherers (Martínez, Zangrando, & Prates, 2009). Besides, studies of oral pathologies showed the increase in the frequency of some variables (e.g., caries and dental calculus) during the last ca. 1000 years BP, due to a higher intake of carbohydrates from vegetables (Flensburg, 2013).

Parallel to the Colorado River, the valley of the Negro River works as the main fluvial corridor of North Patagonia (Figure 1). The middle course of this basin presents an intense archaeological signal between ca. 3000 and 400 years BP, with most of the sites characterized by the overlapping of residential occupations and human burials in sand dunes (Prates & Di Prado, 2013). Although human skeletons cover all the chronological spanning (Prates & Di Prado, 2013; Serna, 2018; Serna & Romano, 2018), there are no pre-1000 years BP-dated residential remains (e.g., fauna, charcoal, and shells). Zooarchaeological analysis suggests that subsistence was focused on the exploitation of terrestrial herbivores, rodents, armadillos, and freshwater mollusks (Mange, 2019; Mange, Prates, González Venanzi, & Di Lorenzo, 2016; Prates et al., 2019; Prates, Di Prado, Mange, & Serna, 2010). Nevertheless, dietary changes over time could not be evaluated

through zooarchaeological analysis because of the lack of data prior to 1000 years BP (Mange et al., 2016; Mange, Ramos Van Raap, & León, 2013; Prates, 2008).

Given this background, the bioarchaeological record is the only empirical mean to evaluate the occurrence of diet changes in the Negro River valley, such as those inferred for the other microregions of northeastern Patagonia. In this paper, we propose to identify paleodiet shifts at ca. 1500–1000 years BP in the Negro River middle valley through the study of the oral health. Dentition and bones are dynamic, plastic, and adaptive systems in response to socioenvironmental pressures (see discussion in Temple & Goodman, 2014), therefore the study of oral pathology offers a useful mean to evaluate —among others— stress events and paleodiet changes (Eshed, Gopher, & Hershkovitz, 2006; Hillson, 1996; Mickleburgh, 2016; Powell, 1985). Caries, dental calculus, *antemortem* tooth loss, and dental wear are used to infer subsistence or as a proxy for the intake of carbohydrates and the hardness of the food (Eshed et al., 2006; Hillson, 1996, 2001; Lanfranco & Eggers, 2010; Powell, 1985; Turner, 1979).

2 | MATERIALS AND METHODS

The analysed sample is composed of 567 teeth (524 permanent and 43 deciduous) and 547 alveoli, corresponding to 32 adult and subadult individuals that were recovered from seven archaeological sites from the middle course of the Negro River, assignable to the late Holocene (ca. 3000–750 years BP; Figure 1, Table 1). All of these sites are located in elevated sand dunes near paleochannels. As mentioned above, human burials and remains of residential occupations (e.g., lithic flakes and pottery) usually coexisted, which has been interpreted as the result of the recurrent occupation of the same places through time due to their features (e.g., proximity to resources, comfortable conditions to camp, and security against flooding). Among these sites, primary burials without funerary goods are predominant (Prates & Di Prado, 2013). All the samples were sexed and aged with standard methods, which can be consulted in other papers (Table 1). The

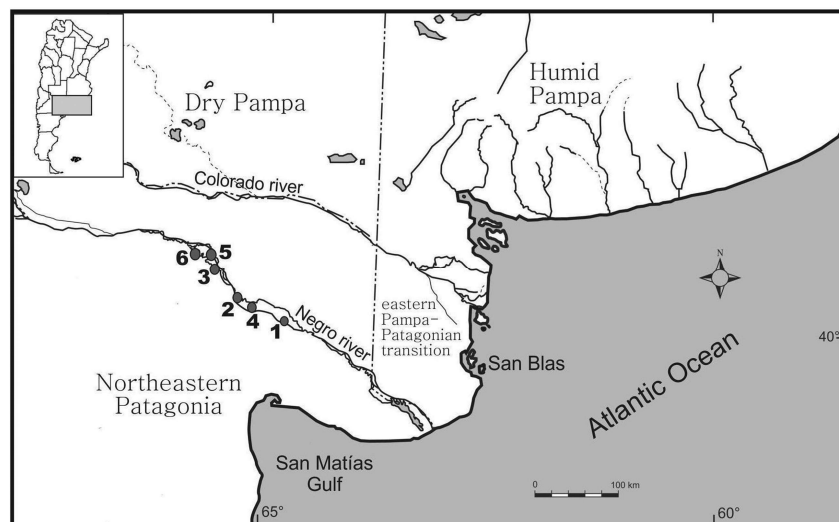


FIGURE 1 Location of the archaeological sites analysed from the middle course of the Negro River.

Note: 1, Loma de los Muertos; 2, Negro Muerto 2 and Negro Muerto 3; 3, Pomona; 4, La Victoria 5; 5, Fábrega; 6, La Toma

TABLE 1 Teeth and alveoli analysed by individual from the middle course of the Negro River

Period	Site	Individual	¹⁴ C	Sex	Age	Reference	N teeth	N alveoli
pre-1000 years BP	Loma de los Muertos	1	2088 ± 46	M	MA	Prates et al., 2010	17	28
		2	3027 ± 48	F	MA		5	11
		3	2718 ± 47	F	YA		12	14
		4	-	Indet.	Indet. adult		5	13
	Negro Muerto 2	1	-	F	MA	Serna, 2018	15	27
		2	1586 ± 47	F	YA		26	28
		3	1637 ± 48	F	YA		15	25
	Negro Muerto 3	1	-	M	YA	Prates et al., 2019	30	32
		2	-	M	MA		32	32
		3	1091 ± 35	M	MA		30	32
		4	-	M	MA		24	29
		5	-	F	MA		17	21
	Subtotal	12	-	-	-	-	228	292
post-1000 years BP	Pomona	1	986 ± 36	M	Indet. adult	Mange, 2018	5	15
	La Victoria 5	1	928 ± 39	F	MA	Prates, Luchsinger, Scabuzzo, & Mansegosa, 2011	25	32
		2	868 ± 48	F	YA		7	6
	Fábrega	1	-	Indet.	Indet. adult	Mange, 2019	8	12
	La Toma	1	750 ± 50	M	MA	Flensburg, Serna, & Mange, 2018	5	14
		2		F	MA		4	16
		3		Indet.	MA		6	16
		4		M	YA		6	16
		5		M	YA		7	10
		6		M	YA		3	8
		7		F	YA		4	15
		8		Indet.	YA		6	20
		9		M	Indet. adult		5	8
		10		Indet.	8 ± 2		12	6
		11		Indet.	8 ± 2		19	-
		12		Indet.	7 ± 2		4	12
		13		Indet.	6 ± 2		7	10
		14		Indet.	5 ± 1.3		5	-
		15		Indet.	4 ± 1		20	-
		16		Indet.	1 ± 0.4		5	5
		-*		Indet.	Indet. adult		158	34
		-*		Indet.	Indet. subadult		18	-
	Subtotal	20	-	-	-	-	339	255
TOTAL		32					567	547

Note. Young adult category represents the range 20-34.9 years and the middle adult category the range 35-50 years (Buikstra & Ubelaker, 1994).

Abbreviations: F, female; Indet., indeterminate; M, male; MA, middle adult; YA, young adult; *, isolated teeth and alveoli that could not be associated with any individual.

remains are currently housed in the Division of Archaeology of the La Plata Museum.

To assess temporal diet changes, the sample was divided into two periods: pre-1000 years BP and post-1000 years BP. The sample of the first period consists of 12 adult individuals of both sexes; of which, 228 teeth and 292 alveoli were analysed. In addition, articular eminences of eight individuals and mandibular condyles of 10 individuals were recorded. The second period is represented by 20 individuals of different ages and both sexes; of which, 339 teeth and 255 alveoli were analysed (Table 1). In this case, articular eminences of six adults and mandibular condyles of seven adults were recorded.

The alveoli, teeth, and joint structures were analysed with a 2×/4× binocular magnifying glass, considering the following variables: caries, calculus, periodontal disease, periapical lesions, *antemortem* tooth loss (AMTL), dental wear, dislocation, and osteoarthritic lesions. Caries

were recorded when cavities in teeth, generated by the demineralization caused by acids during bacterial fermentation of carbohydrates, were observed (Buikstra & Ubelaker, 1994; Hillson, 1996). The location of the lesions was standardized as occlusal, buccal, mesial, distal, and lingual (Hillson, 2001). The dental calculus was analysed according to the amount of mineralized plaque on the surface of the teeth (Brothwell, 1981): low (<1/3), moderate (1/3 to 2/3), and high (>2/3). Periodontal disease was evaluated considering the distance (millimetres) between the alveolar crest and the cement-enamel junction and the appearance and morphology of the buccal contour of the alveolar margins of the posterior teeth (Ogden, 2008). In the periapical lesions, the diameter and the features of the edge of the cavities were analysed (Dias & Tayles, 1997). According to the virulence of the inflammatory process, different outcomes may arise. Although acute infections can cause abscess, the chronic ones are able

to produce periapical granuloma, periodontal cyst, and periapical abscess (Dias, Prasad, & Santos, 2007). The AMTL was recorded considering the porosity of the bone tissue and the alveolar obliteration (Lukacs, 1989). Dental wear was measured with the scoring systems proposed by Smith (1984, grades 1-8) and Scott (1979, grades 1-10) for the anterior and posterior dentition, respectively. The shape and pattern of tooth wear were standardized as flat, buccal-lingual, linguo-buccal, mesio-distal, disto-mesial, and concave (Molnar, 1971). The dental dislocation, which refers to the inclination of the dental crown towards the lingual side and the apexes of the root in the buccal direction (Clarke & Hirsch, 1991; Molnar, 2008), was recorded.

Given that some oral lesions (e.g., AMTL) and high stress in masticatory functions (e.g., dental wear) can generate alterations in the temporomandibular joint (TMJ), degenerative lesions were analysed in the articular eminences and mandibular condyles (Rando & Waldron, 2012). According to Rando and Waldron (2012), eburnation is considered as pathognomonic of TMJ osteoarthritis. In the absence of eburnation, osteoarthritis was diagnosed when two or more of the following lesions were identified: (a) new bone formation on joint surface; (b) new bone formation on joint margins; (c) porosity on joint surface; and (d) modification of joint contour. The lesions were also classified using the ordinal scale of minimum, moderate, and florid expression for the mandibular condyle and the joint eminence separately (Rando & Waldron, 2012).

The lesions were evaluated at the dento-alveolar level. The frequencies were obtained by dividing the total number of teeth/alveoli affected by the total number of teeth/alveoli. The association between their prevalence and sex/age-at-death were tested with χ^2 test. Regarding caries, the corrected caries rate was also calculated (Lukacs, 1995), because the sample shows a large number of AMTL. In the case of dental wear, the analysis was performed at the individual level, adding the scores and generating unique values for the anterior and posterior dentition of each individual. In this case, the differences were evaluated using the Student's *t* test for normal distributions and the nonparametric Mann-Whitney *U* test suitable for small sample sizes (Siegel & Castellan, 1988). The level of statistical significance was established in $\alpha = .05$, and these analyses were performed with SPSS 20 and PAST 3.21 (Hammer, Harper, & Ryan, 2001).

3 | RESULTS

The permanent teeth corresponding to adult individuals presented different degrees of wear, whereas deciduous or permanent teeth of sub-adult individuals showed no wear. This variable does not indicate temporal differences in the anterior ($U = 57.5$, $p = .868$) nor posterior dentition ($U = 61$, $p = .947$), although a greater frequency was observed on M1 in the pre-1000 (Figure 2). In this period, the anterior teeth of females showed greater wear (scores 7.6-8) than males (scores 6.2-6.5), but this difference was not observed in the post-1000 (Figure 3a). In the posterior dentition, the wear is similar in both sexes for each period (scores 25-35, depending on the tooth), mainly affecting the M1 (Figure 3b). In both periods, increasing tooth wear was associated to the increase of age. In the anterior teeth, young adults (YA) present scores between 5.8 and 7.4, and middle adults (MA) scores between 7 and 7.7 (Figure 3c). The same tendency was recorded in the posterior dentition, because the YA present scores between 16 and 36 and MA scores between 28 and 38 (Figure 3d).

For both periods, flat wear predominates (82.5%) in the anterior dentition of adults, followed by the bucco-lingual (17.5%). In the posterior teeth, the flat wear also predominates (42.7%; Figure 4a), and to a lesser extent, the bucco-lingual (32.3%), followed by the disto-mesial (12.7%), and the concave (12.3%). Some anterior ($n = 11$) and posterior ($n = 4$) teeth ($N = 15$; 2.65%) have different wear patterns, characterized by the presence of para-facets and grooves (Fiorenza, Benazzi, & Kullmer, 2011). These facets have a bucco-lingual direction and the grooves, a lateral one (Figure 5). The highest percentage of cases is in the pre-1000 (5.26%; 12/228); whereas the difference is significantly lower in post-1000 (0.89%, 3/338), $\chi^2 = 10.104$, $p = .006$. In both periods, YA and MA females (Figure 5) were more affected than MA males.

All individuals showed post-mortem tooth loss (PMTL; 32.9%; 180/547 of the alveoli), mainly in the post-1000 period (Table 2). In both periods, the highest percentage of PMTL corresponded to I1 (32.8%), I2 (25.5%), and C (11.9%), followed by Pm2 (8.9%), Pm1 (7.5%), M1 (5.9%), M3 (4.6%), and M2 (2.9%). That is, the anterior dentition showed greater PMTL (86.5%) than the posterior dentition (13.5%). Caries, dental calculus, periapical lesions, AMTL, dislocations,

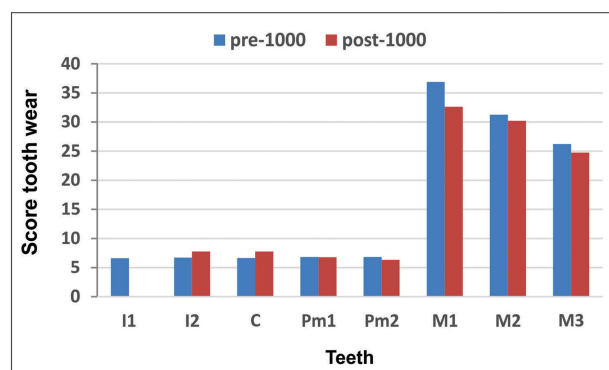


FIGURE 2 Dental wear scores on each tooth for periods (both sexes) [Colour figure can be viewed at wileyonlinelibrary.com]

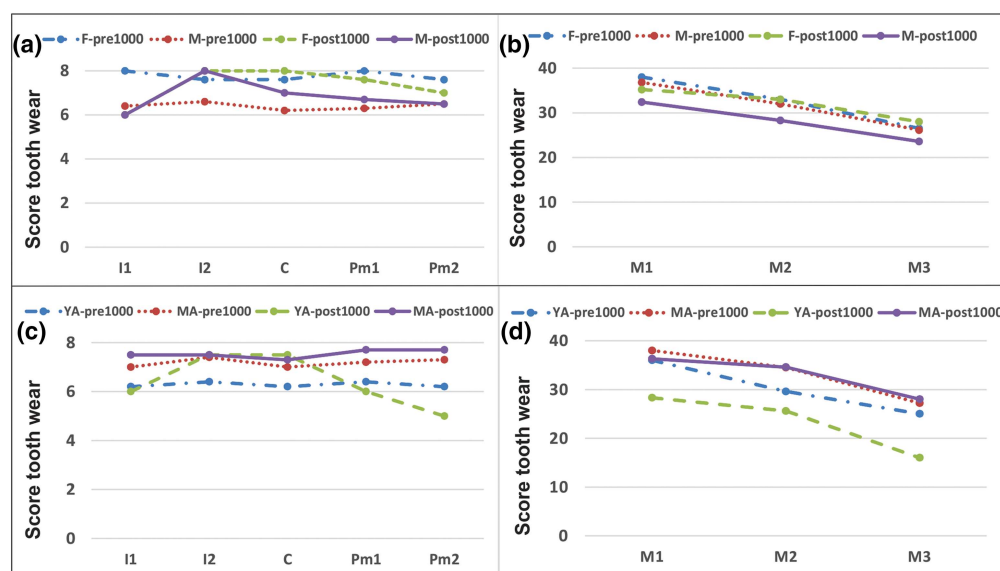


FIGURE 3 Dental wear score by tooth according to (a,b) sex and period; (c,d) adult age category and period. Note: F, female; M, Male; YA, young adult; MA, middle adult [Colour figure can be viewed at wileyonlinelibrary.com]

and TMJ osteoarthritic lesions were recorded in adults, whereas no injuries have been observed in subadults. Alveolar modifications related to periodontal disease were not observed.

Caries were recorded at 3.82% with the correction factor, whereas the frequency of teeth with caries over the total number of teeth analysed gave a percentage of 4.05%. For the latter frequency, similar percentages were observed for both periods (Table 2), without statistical differences ($\chi^2 = 0.953$, $p = .62$) and with a higher prevalence of caries in YA compared with MA (Table 3). No significant differences were observed by sex during the pre-1000 period, whereas in the post-1000, the frequency is higher in men (Table 4). In both periods, caries were recorded on different enamel surfaces: occlusal ($n = 16$; 69.6%), mesial ($n = 2$; 8.7%), distal ($n = 1$; 4.3%), labial ($n = 1$; 4.3%), and lingual ($n = 3$; 13.1%). In pre-1000, caries were recorded in M2 (Figure 4a), whereas in post-1000, it affected I1, M2, and M3.

Dental calculus were recorded in both periods with no statistical differences ($\chi^2 = 1.49$, $p = .474$). The amount of plaque is low, and affected mainly males (Table 4). In pre-1000, there is no significant difference between YA and MA; but in the post-1000, formers were more affected by calculus than MA (Table 3). In pre-1000, dental calculus was observed in C, Pm1, Pm2, and M3; whereas in post-1000, it was registered in I2, Pm1, Pm2, M2, and M3.

Periapical lesion was observed in comparable percentage in both periods (Table 2) ($\chi^2 = 1.524$, $p = .466$). The lesions were recorded at similar frequencies between adult age categories (Table 3). Regarding sex, males predominate during the pre-1000, and there are no differences in the post-1000 (Table 4). The alveoli affected in both periods were C, Pm1, M1, and M2. All lesions are characterized as granuloma (Figure 4b).

AMTL was recorded more frequently in the pre-1000 than in the post-1000 period, ($\chi^2 = 24.174$, $p < .001$; Table 2). The percentages were similar between YA and MA for both periods (Table 3). During the pre-1000, AMTL are more frequent in females than males, with

statistically significant differences (Table 4); whereas in the post-1000, these lesions were recorded only in males. The alveoli affected in the pre-1000 were I1, Pm1, Pm2, M1, M2, and M3 (Figure 4c); whereas in the post-1000, the lesions are located in the M1 and M2.

Dislocations ($n = 12$; 2.11%) were recorded on M1. Although the pre-1000 period showed higher frequency (3.08%; 9/292) than the post-1000 period (1.17%; 3/255), there are no statistical differences ($\chi^2 = 2.304$, $p = .315$). In the first period, YA female individuals were more affected than MA males. In contrast, in the second period, MA males present the majority of injuries (Tables 3 and 4).

Osteoarthrotic lesions were recorded in the mandibular condyles corresponding to individuals from the pre-1000 period (22.2%; 2/9); whereas no joint changes were observed in the articular eminences. The differences were not significant between periods. Minimum lesions characterized by porosity, new bone formation, and changes in the joint contour were recorded in YA males and MA females.

4 | DISCUSSION

4.1 | Tooth wear and oral stress

In both periods, adult males and females present severe dental wear, which affected the normal morphology of the dentition and could have generated alterations in the oral health of the individuals analysed in the middle course of the Negro River during the late Holocene. This indicates that several processes of attrition and abrasion played an important role in the dentition of individuals. In this sense, it is possible that they incorporate abrasive particles in the oral cavity during daily tasks (Jurmain, 1990), because most residential areas are located in dunes, causing exposure of the mouth to suspended sediments; and also during the ingestion of foods or substances processed with grinding tools made on lightly cemented sandstones (Prates, 2008). Besides,

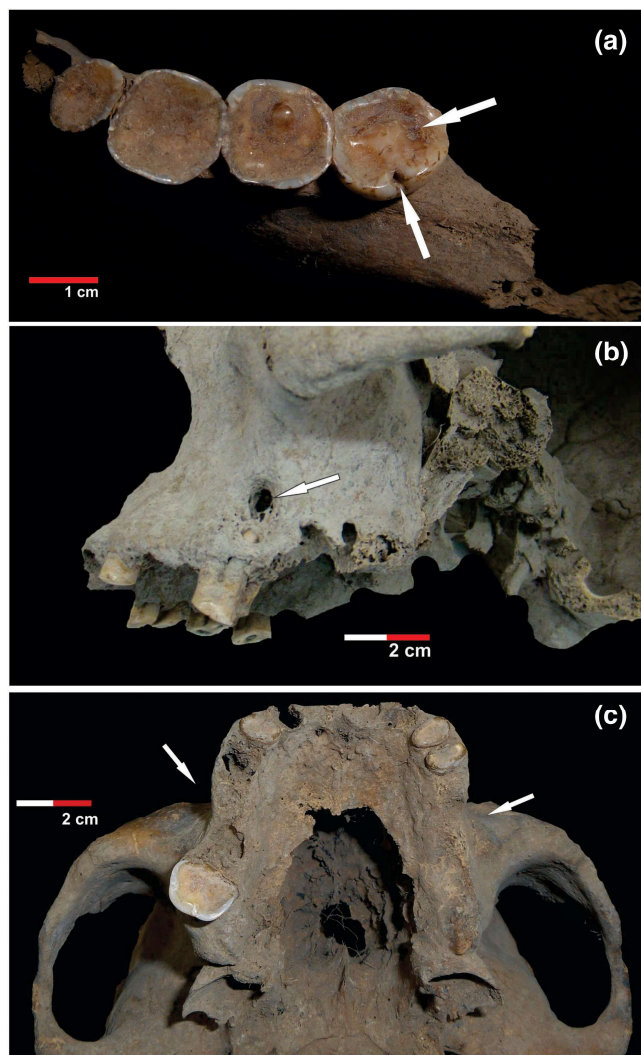


FIGURE 4 (a) Caries on the occlusal and lingual surface in the lower left third molar (NM3-individual 4); (b) granuloma in the left first molar (LM-individual 1); (c) bilateral *antemortem* tooth loss in maxillary premolars and molars (NM3-individual 5) [Colour figure can be viewed at wileyonlinelibrary.com]

in the study area, there is a wide variety of fibrous and hard seeds, pods, tubers, and roots, which could have accelerated the tooth wear (see examples in Cane, 1989; L'Heureux, 2002). In addition, the intake of other abrasive substances (e.g., calcium oxalate phytolith, Lalueza Fox, Jordi, & Albert, 1996) was common in these groups because of cooking meat and vegetables directly on the ashes (e.g., Angostura 1 site; ca. 900 years BP; Capparelli & Prates, 2015), which could also cause tooth wear. Archaeological evidence indicates the extensive use of pottery from ca. 1000 years BP onward (Di Prado, 2016), which generated changes in the preparation of food and probably access to a milder diet. However, the use of this technology did not seem to have generated important variations in the tooth wear and oral health.

According to the wear pattern, the predominance of flat and bucco-lingual shapes in both periods responds to normal occlusion (Hinton, 1981). However, teeth with faceted and grooved wear, mainly for the pre-1000 period (see Prates et al., 2010), would be linked to the parafunctional use of the mouth (Eshed et al., 2006; Fiorenza et al., 2011). This type of wear in male and female individuals shows that there is no sexual pattern in extramasticatory activities. In addition, the higher prevalence in MA indicates the constant use of teeth for functional purposes throughout life (Molnar, 1972; Wood, 1992). This practice could also increase the wear from early age and cause the AMTL, mainly during the pre-1000 period. Although there are no comparative references available for studies on the parafunctional use of the mouth in Patagonia (see other ethnographic and archaeological cases in Molnar, 1972; Kaidonis, Townsend, & Richards, 1993; Bonfiglioli, Mariotti, Facchini, Belcastro, & Condemi, 2004; Eshed et al., 2006; among others), the wear pattern observed in the sample could be the result of processing both vegetable and animal fibres. This is compatible with the recent record of phytoliths associated with leaves and/or stems of grasses (Poaceae) in the dental calculus of some individuals from Negro Muerto 3 site, which could indicate the use of teeth as tools for manipulating vegetable fibres (Prates et al., 2019).

The higher frequency of AMTL in the pre-1000 period indicates that individuals were exposed to greater oral stress than in the post-

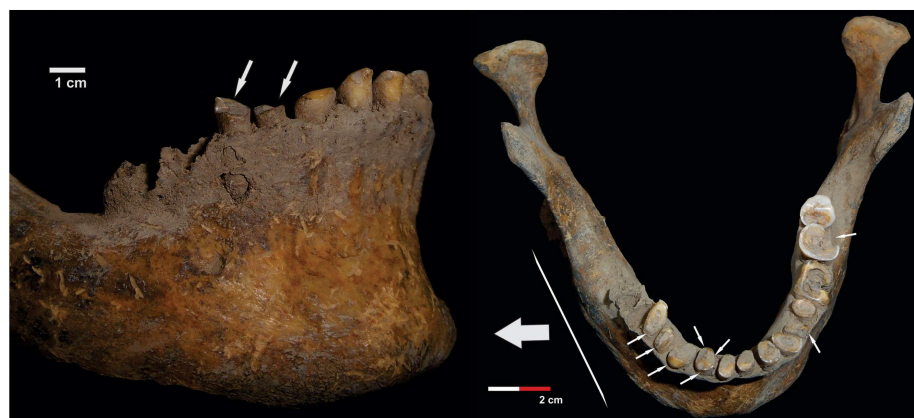


FIGURE 5 *Antemortem* tooth loss in right molars and severe tooth wear in the anterior and posterior dentition (with exposure of the pulp cavity) of a mandible (NM3-individual 5). The arrows indicate the parafaceted wear on each tooth. The left image shows grooves in the right premolars [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Frequency by variables analysed in each period, considering total number of teeth/alveoli affected by the total number of teeth/alveoli

Periods	PMTL		Caries		Dental calculus		Periapical lesion		AMTL		Dislocation		TMJ osteoarthritis	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Pre-1000	56	19.17	7	3.07	11	4.82	6	2.05	32	10.95	9	3.08	2	22.2
Post-1000	124	48.62	16	4.71	25	7.37	2	0.78	2	0.78	3	1.17	0	0
Total	180	32.9	23	4.05	36	6.35	8	1.46	34	6.21	12	2.19	2	13.3

Abbreviations: AMTL, *antemortem* tooth loss; PMTL, *postmortem* tooth loss; TMJ, temporomandibular joint.

TABLE 3 Percentage of dento-alveolar lesions and TMJ osteoarthritis by adult age category in each period and association between variables

Variable	Pre-1000				Post-1000			
	YA	MA	Indet.	χ^2	YA	MA	Indet.	χ^2
Caries	4.67	1.72	0	$\chi^2 = 1.591; p = .451$	3.03	1.2	7.38	$\chi^2 = 0.024, p = .987$
Dental calculus	1.87	7.75	0	$\chi^2 = 4.116; p = .127$	27.3	2.3	9.09	$\chi^2 = 9.647; p = .008^*$
Periapical lesion	2.34	1.98	0	$\chi^2 = 0.041; p = .979$	1.33	1.28	1.22	$\chi^2 = 0.007; p = .996$
AMTL	10.15	12.58	0	$\chi^2 = 0.401; p = .818$	2.6	1.05	2.43	$\chi^2 = 0.381; p = .826$
Dislocation	4.68	1.98	0	$\chi^2 = 1.618; p = .445$	1.5	2.56	0	$\chi^2 = 0.30; p = .861$
TMJ	24	16.6	0	$\chi^2 = 0.104; p = .949$	0	0	0	-

* $p < .05$.

TABLE 4 Percentage of dento-alveolar lesions and TMJ osteoarthritis by sex in each period and association between variables

Variable	Pre-1000				Post-1000			
	F	M	Indet.	χ^2	F	M	Indet.	χ^2
Caries	3.3	3.1	0	$\chi^2 = 0.0187; p = .99$	0	9.67	7.30	$\chi^2 = 4.041, p = .132$
Dental calculus	1.1	7.51	0	$\chi^2 = 4.699; p = .095$	0	12.90	11.79	$\chi^2 = 5.469; p = .064$
Periapical lesion	0.8	3.26	0	$\chi^2 = 2.01; p = .3659$	1.44	1.40	0	$\chi^2 = 0.001; p = .999$
AMTL	19.84	4.57	0	$\chi^2 = 11.307; p < .003^*$	0	2.81	0	$\chi^2 = 1.971; p = .373$
Dislocation	4.76	0.65	0	$\chi^2 = 4.767; p = .092$	0	2.81	0	$\chi^2 = 1.978; p = .375$
TMJ	32.21	14.28	0	$\chi^2 = 0.476; p = .788$	0	0	0	-

* $p < .05$.

1000 period. Although the origin of AMTL is multifactorial (e.g., infection of the pulp cavity, caries, dental fracture, severe attrition, and periodontal disease; Littleton & Frohlich, 1993; Nelson, Lukacs, & Yule, 1999; Lukacs, 2007), in this study case, a high wear by attrition and/or abrasion was observed in all dental pieces, mainly in MA individuals, which caused a reduction in tooth enamel. This process may have generated physiological responses (e.g., continuous eruption) in the organism to maintain functional dental occlusion and facial height, causing in extreme conditions the loss of teeth (Clarke & Hirsch, 1991; Glass, 1991). In addition, the exposure of the dentin and the pulp cavity (Figure 5) to the oral environment increases the chances of causing a foci of alveolar infection and, therefore, to the definitive loss of the teeth (e.g., M1; Bernal, Novellino, González, & Perez, 2007; Ogden, 2008; Fujita et al., 2013). According to the results, individuals lost their teeth at early ages in both periods, probably due to severe masticatory stress. The higher frequency of AMTL in female individuals (Table 4) could be related to greater wear than males (Figure 3a,b). However, it is not ruled out that caries could cause AMTL (Cusina & Tiesler,

2003; Fujita et al., 2013; Jurmain, 1990; Lukacs, 2007). The latter is congruent with the fact that the second molars of females were the most affected by caries and AMTL.

Dental dislocation, as a physiological response to the loss of tooth tissue by attrition and abrasion (Clarke & Hirsch, 1991), is another indicator of an excessive demand in the performance of the masticatory apparatus mainly in the pre-1000 period. The location of the lesion in the first molars of females also supports the trend of greater stress in this sex (Table 4). In addition, dental wear associated with dislocations and AMTL in greater frequency during the pre-1000 period, would have affected the structure of the temporomandibular joint and contributed to the development of osteoarthrotic lesions (Lovell, 2014; Suby & Giberto, 2018; Whittaker, Davies, & Brown, 1985).

Periapical lesions are caused by an infection of the pulp cavity because of exposure to oral bacteria through caries, attrition, or trauma (Dias & Tayles, 1997). Here, only granulomas were observed in teeth with severe tooth wear and signs of continuous eruption (Figure 4b). Therefore, the exposure of blood vessels located in the

pulp chamber to the oral environment could allow the entry of bacteria into the organism and, consequently, cause periapical infections and the alveolar bone loss associated with bone fenestrations (Dias et al., 2007; Kieser, Kelsen, Love, Herbison, & Dennison, 2001). The frequency of lesions observed in both periods suggests that chronic alveolar inflammations would not have been frequent.

4.2 | Oral pathology and the role of carbohydrates in the diet

In the dentition, no indicators of *premortem* or *postmortem* dental cleaning were observed, which could have biased the caries and dental calculus survey. Besides, the high percentage of PMTL, mainly in anterior teeth, can bias the inferences. However, this work offers the first trend regarding oral health in the middle course of the Negro River.

The low and similar percentage of caries regardless sex and age in both periods indicates that dental infections were not frequent through the late Holocene. During the pre-1000 period, both sexes were affected in similar proportions, which do not indicate differences in access to cariogenic and carbohydrate-rich food resources. In contrast, the post-1000 period showed a larger prevalence in males, but this result is probably due to a sex bias in the sample because there are several teeth that have caries correspond to the category of indeterminate sex (Table 4).

The prevalence of caries obtained in this sample is low and is within the ranges expected for the hunter-gatherer's way of life proposed by Turner (1979; between 0% and 5.3%) and by Larsen (1987; between 0% and 7.8%). In this case, the low prevalence of caries could be related with two nonexclusive factors. On the one hand, a reduced carbohydrate intake (Bernal et al., 2007; Bonfiglioli, Brasili, & Belcastro, 2003; Eshed et al., 2006; Hillson, 2001; Larsen, Shavit, & Griffin, 1991). In the study area, there is a diversity of plant and vegetable species that offers products rich in sugars, sticky foods, and carbohydrates (e.g., *Prosopis alba* and *Prosopis flexuosa*; Roig, 1993). In some cases, they present direct evidence of their consumption from the presence of fruits of the genus *Prosopis* in residential areas (Capparelli & Prates, 2015) and micro-rests of *Zea mays* and *Prosopis* sp. in dental calculus (Prates et al., 2019). The results obtained in this study could indicate that these resources had a reduced importance in the human diet through the late Holocene. On the other hand, the severe attrition and abrasive processes inferred from high dental wear, particularly in MA (Figure 3c,d), may have contributed to the elimination of previous caries and bacterial plaques responsible for demineralizing the enamel (Hillson, 1996; Meiklejohn, Wyman, & Schentag, 1992). The location of the caries mainly on complex surfaces of posterior dentition (M2/M3) that act as food traps (e.g., cusps and grooves; Hillson, 2001, Bonfiglioli et al., 2003) shows that the bacteria were deposited on teeth with less wear (Figure 3). Therefore, the percentage of caries recorded here could be underestimated by the dental wear.

The results of dental calculus indicate that through the late Holocene, individuals would have had a low precipitation of minerals in

the oral fluids (i.e., saliva and gingival fluids) by the action of bacterial microorganisms (Hillson, 2001; Nancollas & Johnsson, 1994). This result agrees with the lack of periodontal disease, because it is usually caused by the accumulation of subgingival plaque and the consequently inflammation of the gums (DeWhitte, 2012; Marsh & Martin, 2000). Besides the pH of the saliva and the general oral hygiene, the food intake is also a contributing factor for the formation of calculus (Lieverse, 1999). Some authors propose that dental calculus may be mainly related to consumption of protein-rich food (e.g., fish or meat; Lieverse, 1999; Delgado-Darias et al., 2006), whereas others indicate that diets rich in carbohydrates may promote the formation of bacterial plaque (Littleton and Frohlich, 1993; Buckley, Usai, Jakob, Radini, & Hardy, 2014). The higher prevalence of dental calculus in the dentition of YA of the post-1000 period could be related to variations in diet and oral hygiene. However, the overall frequencies observed over time do not indicate dietary changes in the hunter-gatherer groups. The interpretations outlined here should be considered with caution due to the analysis of a small sample of individuals and that presents a significant amount of PMTL, mainly in anterior dentition. All interpretations should be tested in the future with a larger sample.

4.3 | Oral health on a regional scale

The oral health indicators analysed in this paper fit well with the trends reported for hunter-gatherer societies from other regions of southern South America such as northeastern Patagonia, Dry Pampas, and Humid Pampas (Figure 1; Table 5). However, in Humid Pampas, eastern Pampa-Patagonian transition and lower course of Negro River an increase in the frequency of caries, dental calculus, and periodontal disease was observed for post-1000 years BP. This was linked to an increase in the intake of vegetable resources rich in carbohydrates (Flensburg, 2013; L'Heureux, 2000; Menéndez, 2010) and to changes in the ways of processing food (Menéndez, 2016). This would have occurred in a scenario of diet diversification, including intensification in the consumption of fruits and tubers and the introduction of pottery technology, which implied new ways of preparing food (e.g., boiled) from 1500 years BP (Flensburg, 2013; L'Heureux, 2000; Menéndez, 2010). In the middle course of the Negro River, even with the frequent use of pottery (Di Prado, 2016), no changes in the frequency of caries and dental calculus were observed during the late Holocene. Similar trends in oral pathologies were reported for other neighbouring regions located in steppe environments from northeastern Patagonia, where no changes were detected over time (Bernal et al., 2007; Gómez Otero & Novellino, 2011). On the basis of the study of samples from the lower course of the Negro River, San Blas, and Gama islands, Bernal et al. (2007) proposed that the low prevalence of caries in the last ca. 1000 years BP could be also due to the low consumption of carbohydrates. In other words, although plant intake was always part of the diet, its role was not probably as important as it was in other regions.

The differences between the regions can be related to the availability of resources in the environment. In this sense, it is possible that in the study area the plant species represented in the Monte

TABLE 5 Percentage of oral pathologies at the dento-alveolar level in neighbouring microregions during the late Holocene

Microregion	Chronology YBP	N teeth	N alveoli	Caries	Periapical lesion	AMTL	Dental calculus	Periodontal disease	References
Humid Pampas	ca. 8000-400	838	1067	10.6	4.8	1.4	67.37	1.6	L'Heureux, 2000
Dry Pampas	ca. 1000-350	806	724	0	3.29	7.9	38.83	22.55	Luna & Aranda, 2014
Eastern Pampa-Patagonia transition	ca. 3000-250	974	1260	4.7	2.6	6.6	24.2	2.1	Flensburg, 2013
Lower course Negro River	ca. 3000-400	1317	2996	2.3 ^a	2.8	2.4	v/n	7.9	Menéndez, 2010
Lower course Negro River-San Blas-Gama Islands	ca. 3000-400	821	n/r	0.5-1.25	v/n	6.3	v/n	v/n	Bernal et al., 2007
Middle course Negro River	ca. 3000-750	567	547	4.05 3.82 ^a	1.46	6.21	6.35	0	This paper

Note. All frequencies were obtained by dividing the total number of teeth/alveoli affected by the total number of teeth/alveoli.

Abbreviations: n/r, not reported; v/n, variable not analysed.

^aFrequency obtained by the Caries Correction Factor (Lukacs, 1995).

phytogeographic region offer fewer products with carbohydrates (e.g., fruits) in comparison with the Espinal phytogeographic region where the eastern Pampa-Patagonian transition is located (Cabrera & Willink, 1973; Roig, Roig-Juñent, & Corbalán, 2009). However, the differences between regions can also be explained by variations in tooth wear, which in some cases conditioned the presence of some indicators (e.g., caries and dental calculus) (Flensburg, 2013; Gómez Otero & Novellino, 2011; L'Heureux, 2002). To explore this idea, the variation in the degrees of tooth wear of individuals between the middle course of the Negro River and the neighbouring eastern Pampa-Patagonian transition was evaluated. The first region has a larger overall degree of dental wear in both, anterior ($U = 694.5$, $p = .006$) and posterior dentition ($t = 3.360$, $p = .001$) than the second region. In this sense, some variations in the frequency of dental pathologies (e.g., caries) in the study area could be conditioned by tooth wear. In sum, the results indicate that in the middle Negro River, severe abrasive processes occurred between ca. 3000 and 750 years BP without showing changes, most likely due to diet abrasiveness and hard texture and parafunctional use of dentition.

5 | CONCLUSIONS

The analysis of dento-alveolar lesions in the late Holocene samples from the middle course of the Negro River suggests a low intake of carbohydrate and does not show evidences of diet changes over time in hunter-gatherers groups. Although tooth wear could have prevented the observation of some dental features, there were no significant changes in the alimentary habits and/or physiological adaptations in human groups. Anyway, for the pre-1000 period, there is a greater frequency of AMTL, teeth with parafunctional wear, dental dislocations, and osteoarthritis in mandibular condyles, which indicates that individuals would have been exposed to greater stress in chewing than in the post-1000 period. These differences are probably a result

of a softer diet during later times, associated with the use of pottery technology. If so, it would not have been sufficient to produce greater dental infections (e.g., caries) unless these are not observable due intense attrition and abrasive processes. In this sense, it will be necessary to explore other lines of analysis (e.g., stable isotopes) to evaluate the role of vegetables in the human diet. Finally, if subsistence changes occurred around 1000 years BP among hunter-gatherers of the study area, these were not as important as those occurred in neighbouring regions such as the Humid Pampas, eastern Pampa-Patagonian transition, and lower course of Negro River.

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REFERENCES

- Bernal, V., Novellino, P., González, P., & Perez, S. I. (2007). Role of wild plant foods among Late Holocene hunter-gatherers from Central and North Patagonia (South America): An approach from dental evidence. *American Journal of Physical Anthropology*, 133, 1047–1059.
- Bonfiglioli, B., Brasili, P., & Belcastro, M. G. (2003). Dento-alveolar lesions and nutritional habits of a Roman Imperial age population (1st.4th c. AD): Quadrella (Milise, Italy). *HOMO-Journal of Comparative Human Biology*, 54(1), 36–56.
- Bonfiglioli, B., Mariotti, V., Facchini, F., Belcastro, M. G., & Condemi, S. (2004). Masticatory and non-masticatory dental modifications in the epipalaeolithic necropolis of Taforalt (Morocco). *International Journal of Osteoarchaeology*, 14, 448–456.

- Brothwell, D. R. (1981). *Digging up bones*. New York: Cornell University Press.
- Buckley, S., Usai, D., Jakob, T., Radini, A., & Hardy, K. (2014). Dental calculus reveals unique insights into food items, cooking and plant processing in prehistoric Central Sudan. *PLoS ONE*, 9(7), e100808.
- Buikstra J, Ubelaker D. 1994. Standars for data collection from human skeletal remains. Arkansas Archaeological Survey Research Series N° 44, Arkansas.
- Cabrera, A. L., & Willink, A. (1973). *Biogeografía de América Latina*. Washington, DC: Organización de los Estados Americanos.
- Cane, S. (1989). Australian aboriginal seed grinding and its archaeological record: A case study from the Western Desert. In D. Harris, & G. Hillman (Eds.), *The Evolution of Plant Exploitation* (pp. 99–119). London, UK: One World Archaeology Series. Unwin Hyman.
- Capparelli, A., & Prates, L. (2015). Explotación de frutos de algarrobo (*Prosopis* sp.) por grupos cazadores-recolectores del noreste de Patagonia. *Chungará, Revista de Antropología Chilena*, 47(4), 549–563.
- Clarke, N. G., & Hirsch, R. S. (1991). Physiological, pulpal, and periodontal factors influencing alveolar bone. In M. A. Kelley, & C. S. Larsen (Eds.), *Advances in dental anthropology* (pp. 241–266). New York: Wiley-Liss.
- Cordero, J. A. (2012). Las prácticas de subsistencia de las sociedades cazadoras-recolectoras del noroeste de la Patagonia argentina a lo largo del Holoceno. *Archaeofauna*, 21, 99–120.
- Cusina, A., & Tiesler, V. (2003). Dental caries and antemortem tooth loss in the Northern Peten Area, Mexico: A biocultural perspective on social status differences among the Classic Maya. *American Journal of Physical Anthropology*, 122, 1–10.
- Delgado-Darias, T., Velasco-Vázquez, J., Arnay-de-la-Rosa, M., Martín-Rodríguez, E., & González-Reimers, E. (2006). Calculus, periodontal disease and tooth decay among the prehispanic population from Gran Canaria. *Journal of Archaeological Science*, 33, 663–670.
- DeWhitte, S. N. (2012). Sex differences in periodontal disease in catastrophic and attritional assemblages from Medieval London. *American Journal of Physical Anthropology*, 149, 405–416.
- Di Prado, V. (2016). Prácticas de elaboración y uso de la alfarería prehispánica del este de Norpatagonia. *Relaciones de la Sociedad Argentina de Antropología*, XLI(2), 397–419.
- Dias, G., Prasad, K., & Santos, A. L. (2007). Pathogenesis of apical periodontal cysts: Guidelines for diagnosis in palaeopathology. *International Journal of Osteoarchaeology*, 17, 619–626.
- Dias, G., & Tayles, N. (1997). "Abscess cavity"—A misnomer. *International Journal of Osteoarchaeology*, 7, 548–554.
- Eshed, V., Gopher, A., & Hershkovitz, I. (2006). Tooth wear and dental pathology at the advent of agriculture: New evidence from the Levant. *American Journal of Physical Anthropology*, 130, 145–159.
- Favier Dubois, C., Borella, F., & Tykot, R. H. (2009). Explorando tendencias en el uso humano del espacio y los recursos en el litoral rionegrino (Argentina) durante el Holoceno medio y tardío. In M. Salemm, F. Santiago, M. Álvarez, E. Piana, M. Vázquez, & M. E. Mansur (Eds.), *Arqueología de la Patagonia: una mirada desde el último confín* (pp. 985–997). Tierra del Fuego: Editorial Utopías, Ushuaia.
- Fiorenza, L., Benazzi, S., & Kullmer, O. (2011). Para-masticatory wear facets and their functional significance in hunter-gatherer maxillary molars. *Journal of Archaeological Science*, 38, 2182–2189.
- Flensburg, G. (2013). Paleopatologías bucales y tendencias paleodietarias en grupos cazadores-recolectores de la transición pampeano-patagónica oriental, durante el Holoceno tardío. *Relaciones de la Sociedad Argentina de Antropología*, XXXVIII(1), 199–222.
- Flensburg, G., Serna, A., & Mange, E. (2018). Estudio bioarqueológico del sitio La Toma (curso medio del Río Negro, provincia de Río Negro). *Relaciones de la Sociedad Argentina de Antropología*, XLIII(1), 113–133.
- Fujita, H., Suzuki, T., Shoda, S., Kawakubo, Y., Ohno, K., Giannakopoulou, P., & Harihara, S. (2013). Contribution of antemortem tooth loss (AMTL) and dental attrition to oral palaeopathology in the human skeletal series from the Yean-ri site, South Korea. *International Journal of Archaeology*, 1(1), 1–5.
- Glass, G. B. (1991). Continuous eruption and periodontal status in pre-industrial dentitions. *International Journal of Osteoarchaeology*, 1, 265–271.
- Gómez Otero J. 2007. Dieta, uso del espacio y evolución en poblaciones cazadoras-recolectoras de la costa centroseptentrional de Patagonia durante el Holoceno medio y tardío. Unpublished PhD dissertation. Facultad de Filosofía y Letras, UBA, Buenos Aires.
- Gómez Otero, J., & Novellino, P. (2011). Diet, nutritional status and oral health in hunter-gatherers from the Central-Northern Coast of Patagonia and the Chubut River Valley, Argentina. *International Journal of Osteoarchaeology*, 21, 643–659.
- Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). PAST. Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, 4, 1–9.
- Hillson, S. (1996). *Dental anthropology*. Cambridge: Cambridge University Press.
- Hillson, S. (2001). Recording dental caries in archaeological human remains. *International Journal of Osteoarchaeology*, 11, 249–289.
- Hinton, R. J. (1981). Form and patterning of anterior tooth wear among aboriginal human groups. *American Journal of Physical Anthropology*, 54, 555–564.
- Jurmain, R. (1990). Paleoepidemiology of a central California prehistoric population from CA-Ala-329: dental disease. *American Journal of Physical Anthropology*, 81, 323–342.
- Kaidonis, J. A., Townsend, G. C., & Richards, L. C. (1993). Nature and frequency of dental wear facets in an Australian aboriginal population. *Journal of Oral Rehabilitation*, 20, 333–340.
- Kieser, J. A., Kelsen, A., Love, R., Herbison, P. G. P., & Dennison, K. J. (2001). Periapical lesions and dental wear in the Early Maori. *International Journal of Osteoarchaeology*, 11, 290–297.
- L'Heureux, G. L. (2002). Inferencias paleodietarias a partir del análisis de los patrones de desgaste dental y frecuencia de caries en muestras de restos humanos del Holoceno del sudeste de la Región Pampeana. In D. Mazzanti, M. Berón, & F. Oliva (Eds.), *Del Mar a Los Salitrales, 10000 años de historia pampeana en el umbral del tercer milenio* (pp. 127–140). Universidad Nacional de Mar del Plata.
- L'Heureux, G. L. (2000). Estudio comparativo de indicadores de adecuación fisiológica y salud bucal en muestras de restos humanos del sudeste de la región Pampeana. *Relaciones de la Sociedad Argentina de Antropología*, XXV, 51–73.
- Lalueza Fox, C., Jordi, J., & Albert, R. M. (1996). Phytolith analysis on dental calculus, enamel surface and burial soil: Information about diet and paleoenvironment. *American Journal of Physical Anthropology*, 101, 101–113.
- Landfranco, L. P., & Eggers, L. (2010). The Usefulness of caries frequency, depth, and location in determining cariogenicity and past subsistence: A test on early and later agriculturalist from the Peruvian coast. *American Journal of Physical Anthropology*, 143, 75–91.
- Larsen, C. S. (1987). Bioarchaeological interpretation of subsistence economy and behavior from human skeletal remains. *Advances in Archaeological Method and Theory*, 10, 339–445.

- Larsen, C. S., Shavit, R., & Griffin, M. C. (1991). Dental caries evidence for dietary change: An archaeological context. In M. Kelley, & C. Larsen (Eds.), *Advances in Dental Anthropology* (pp. 179–202). New York: Willey-Liss.
- Lieverse, A. R. (1999). Diet and the aetiology of dental calculus. *International Journal of Osteoarchaeology*, 9, 219–232.
- Littleton, J., & Frohlich, B. (1993). Fish-eaters and farmers: Dental pathology in the Arabian Gulf. *American Journal of Physical Anthropology*, 92, 427–447.
- Lovell, N. (2014). Occlusal macrowear, antemortem tooth loss, and temporomandibular joint arthritis at predynastic Naqada, Egypt. In R. Metcalfe, J. Cockitt, & R. David (Eds.), *Palaeopathology in Egypt and Nubia: A century in review* (Vol. 6) (pp. 95–106). London, UK: Archaeopress Egyptology.
- Lukacs, J. R. (1989). Dental paleopathology: Methods for reconstructing dietary patterns. In M. Iscan, & K. Kennedy (Eds.), *Reconstruction of Life from the Skeleton* (pp. 261–286). New York: Alan R. Liss.
- Lukacs, J. R. (1995). The “caries correction factor”: A new method of calibrating dental caries rates to compensate for antemortem loss of teeth. *International Journal of Osteoarchaeology*, 5, 151–156.
- Lukacs, J. R. (2007). Dental trauma and antemortem tooth loss in prehistoric canary islanders: Prevalence and contributing factors. *International Journal of Osteoarchaeology*, 17, 157–173.
- Luna, L. H., & Aranda, C. M. (2014). Trends in oral pathology of hunter-gatherers from Western Pampas, Argentina. *Anthropological Science*, 122(2), 55–67.
- Mange E. 2019. Investigaciones arqueológicas en la margen sur del valle medio-superior del río Negro (pcia de Río Negro). Ph.D. Thesis, Department of Archaeology, University of La Plata.
- Mange, E., Prates, L., González Venanzi, L., & Di Lorenzo, M. (2016). El registro faunístico del sitio Negro Muerto 3 (provincia de Río Negro, Argentina): tafonomía y patrones de explotación. *Comechingonia. Revista de Arqueología*, 20(1), 231–252.
- Mange, E., Ramos Van Raap, A., & León, D. (2013). La arqueofauna del sitio Loma de los Muertos (departamento de General Conesa, Río Negro). *Intersecciones en Antropología*, 14(2), 301–314.
- Marani H. 2016. Aprovechamiento de vertebrados terrestres por las poblaciones humanas que habitaron la costa del Golfo San Matías (provincia de Río Negro, Argentina) durante el Holoceno medio y tardío. Ph.D. Thesis, Department of Archaeology, University of La Plata.
- Marsh, P., & Martin, M. (2000). *Oral microbiology* (Fourth ed.). England: Wright.
- Martínez G. (ed.). 2017. Arqueología de cazadores-recolectores del curso inferior del Río Colorado (provincia de Buenos Aires, Argentina). Aportes al conocimiento de las ocupaciones humanas Pampeano-Patagónicas. Serie Monográfica 6, INCUAPA, Olavarría.
- Martínez, G., Zangrando, A. F., & Prates, L. (2009). Isotopic ecology and human palaeodiets in the Lower Basin of the Colorado river, Buenos Aires Province, Argentina. *International Journal of Osteoarchaeology*, 19, 281–296.
- Meiklejohn, C., Wyman, J. W., & Schentag, C. T. (1992). Caries and attrition: Dependent or independent variables? *International Journal of Anthropology*, 7, 17–22.
- Menéndez, L. (2010). Patologías bucales en cráneos humanos del noreste de Patagonia: tendencias temporales en la dieta y estado de salud de las poblaciones del Holoceno tardío del valle inferior del Río Negro. *Magallania*, 38(2), 115–126.
- Menéndez, L. (2016). Spatial variation of dental caries in Late Holocene samples of Southern South America: A geostatistical study. *American Journal of Human Biology*, 28, 825–836.
- Mengoni, G. G. (1999). *Cazadores de guanacos de la estepa patagónica*. Buenos Aires: Sociedad Argentina de Antropología.
- Mickleburgh, H. L. (2016). Dental wear and pathology in the precolonial caribbean: Evidence for dietary change in the Ceramic Age. *International Journal of Osteoarchaeology*, 26, 290–302.
- Miotti, L. (2012). El uso de los recursos faunísticos entre los cazadores-recolectores de Patagonia: tendencias espacio/temporales de las estrategias durante el Holoceno. *Archaeofauna*, 21, 137–160.
- Miotti, L., & Salemme, M. (2004). Poblamiento, movilidad y territorios entre las sociedades cazadoras-recolectoras de Patagonia. *Complutum*, 15, 177–206.
- Molnar, P. (2008). Dental wear and oral pathology: Possible evidence and consequences of habitual use of teeth in a Swedish Neolithic sample. *American Journal of Physical Anthropology*, 136, 423–431.
- Molnar, S. (1971). Human tooth wear, tooth function, and cultural variability. *American Journal of Physical Anthropology*, 34, 175–190.
- Molnar, S. (1972). Tooth wear and culture: a survey of tooth functions among some prehistoric populations. *Current Anthropology*, 13, 511–526.
- Nancollas, G. H., & Johnsson, M. A. S. (1994). Calculus formation and inhibition. *Advances in Dental Research*, 8, 307–311.
- Nelson, G. C., Lukacs, J. R., & Yule, P. (1999). Dates, caries, and early tooth loss during the Iron Age of Oman. *American Journal of Physical Anthropology*, 108, 333–343.
- Ogden, A. R. (2008). Advances in the paleopathology of teeth and jaws. In S. Mays, & R. Pinhasi (Eds.), *Advances on Human Paleopathology* (pp. 283–308). West Sussex: John Wiley & Sons.
- Powell, M. L. (1985). The analysis of dental wear and caries for dietary reconstruction. In R. I. Gilbert, & J. H. Mielke (Eds.), *The Analysis of Prehistoric Diets* (pp. 307–338). Orlando: Academic Press.
- Prates, L. (2008). Los indígenas del río Negro. In *Un enfoque arqueológico*. Buenos Aires: Sociedad Argentina de Antropología.
- Prates, L., & Di Prado, V. (2013). Sitios con entierros humanos y ocupaciones residenciales en la cuenca del río Negro (Norpatagonia, Argentina). *Diacronía y multicausalidad. Latin American Antiquity*, 24 (4), 541–466.
- Prates, L., Di Prado, V., Mange, E., & Serna, A. (2010). Sitio Loma de los Muertos. Múltiples ocupaciones sobre un médano del este de Norpatagonia (Argentina). *Magallania*, 38(1), 163–179.
- Prates, L., Luchsinger, H., Scabuzzo, C., & Mansegosa, D. (2011). Investigaciones arqueológicas en el sitio La Victoria 5 (departamento de General Conesa, Río Negro). *Intersecciones en Antropología*, 12, 155–167.
- Prates, L., Serna, A., Mange, E., López, L., Romano, V., Di Lorenzo, M., ... González, V. L. (2019). Ocupaciones residenciales y entierros humanos en Negro Muerto 3 (valle del río Negro, Norpatagonia). *Magallania*, 47 (1). in press
- Rando, C., & Waldron, T. (2012). TMJ Osteoarthritis: A new approach to diagnosis. *American Journal of Physical Anthropology*, 148, 45–53.
- Roig FA. 1993. Informe nacional para la selección de germoplasma en especies de Prosopis de la República Argentina. In Unidades Botánica y Fisiología Vegetal, IADIZA (ed.), Contribuciones Mendocinas a la Quinta Reunión Regional para América Latina y El Caribe de la Red de Forestación del CIID; 1-37.
- Roig, F. A., Roig-Juñent, S., & Corbalán, V. (2009). Biogeography of the Monte Desert. *Journal of Arid Environments*, 73, 164–172.

- Scott, E. C. (1979). Dental wear scoring technique. *American Journal of Physical Anthropology*, 51, 213–218.
- Serna A. 2018. Interacciones sociales en el noreste de Patagonia durante el Holoceno tardío: un enfoque bioarqueológico. Ph.D. Thesis, Department of Archaeology, University of La Plata.
- Serna, A., & Romano, V. (2018). Rescates bioarqueológicos en el valle medio del río Negro (provincia de Río Negro): el potencial informativo del registro altamente perturbado. *Revista Argentina de Antropología Biológica*, 20(2). <https://doi.org/10.17139/raab.2018.0020.02.03>
- Siegel, S., & Castellan, N. J. (1988). Nonparametric statistics for the behavioral sciences. In *Statistics* (2nd ed.). New York: McGraw-Hill.
- Smith, B. H. (1984). Patterns of molar wear in hunter-gatherers and agriculturalists. *American Journal of Physical Anthropology*, 63, 39–56.
- Stoessel, L., & Alcaráz, A. P. (2017). Los conjuntos faunísticos. Subsistencia y tafonomía. In G. Martínez (Ed.), *Arqueología de cazadores-recolectores del curso inferior del río Colorado (provincia de Buenos Aires, Argentina). Aportes al conocimiento de las poblaciones humanas pampeano-patagónicas. Serie monográfica N°6.* (pp. 100–120). Olavarría: INCUAPA-CONICET-UNICEN.
- Suby, J. A., & Giberto, D. A. (2018). Temporomandibular joint osteoarthritis in human ancient skeletal remains from late Holocene in southern Patagonia. *International Journal of Osteoarchaeology*, 29(1), 14–25. <https://doi.org/10.1002/oa.2709>
- Temple, D., & Goodman, A. (2014). Bioarcheology has a “Health” problem: Conceptualizing “Stress” and “Health” in bioarcheological research. *American Journal of Physical Anthropology*, 155, 186–191.
- Turner, I. I. C. G. (1979). Dental anthropological indications of agriculture among the Jomon people of central Japan. *American Journal of Physical Anthropology*, 51, 619–636.
- Whittaker, D., Davies, G., & Brown, M. (1985). Tooth loss, attrition and temporomandibular joint changes in a Romano-British population. *Journal of Oral Rehabilitation*, 12, 407–419.
- Wood SR. 1992. Tooth wear and the sexual division of labour in an Inuit population. Thesis Master of Arts, Department of Archeology, Simon Fraser University.
- Zangrando, A. F. J. (2009). Is fishing intensification a direct route to hunter-gatherer complexity? A case study from the Beagle Channel region (Tierra del Fuego, southern South America). *World Archaeology*, 41(4), 589–608.

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