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Diet and Oral Health of Populations that Inhabited Central Argentina (Córdoba Province) during Late Holocene

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ABSTRACT The aim of this work is to study, from a bioarchaeological perspective, the diet and oral health of the populations that inhabited Central Argentina in two periods which would reflect changes in subsistence strategies: earlier late Holocene (ca. 2500–1500 years BP) and later late Holocene (ca.1500–400 years BP). The sample is composed by 83 adult individuals from 47 archaeological sites. We considered five non-specific indicators of stress, infectious and degenerative diseases: hypoplasia of dental enamel, dental caries, abscesses, antemortem teeth loss, and calculus. We also considered hypercementosis, dens in dens, and agenesis. We test intraobserver error by means of intraclass correlation coefficient and analysis of variance of repeated measures. We calculated prevalence by sex, age, geographic subregion, and chronological period. We applied Chi-square (X^2) to test statistical significance of observed differences. Considering the sample as a whole, low prevalence of dental caries (10.27%), abscesses (16.52%), and hypoplasia (10.84%) are coincident with values observed for populations with mixed or hunter-gathering subsistence strategy. In later late Holocene, high incidence of caries should be considered as indicator of consumption of C4 vegetables or other carbohydrate-rich vegetables, such as legumes of *Prosopis* sp. Also, moderate values of dental enamel hypoplasia should be related with metabolic-systemic stress episodes. Summarizing, these results are coincident with isotopic, archaeological, and ethnohistorical evidences which suggest climatic, social, and demographic pressures that might have affected the lifestyle of these populations before the Spanish conquest.

Key words: Argentina; Córdoba; diet; Holocene; hunter-gatherer subsistence system; oral health; pre-hispanic agriculture

Introduction

As part of the archaeological record, teeth are one of the best conserved elements over time, which can provide information about diet, nutrition, metabolic and nutritional stressors, as well as parafunctional activities. This information, added to other archaeological evidence, can contribute to the study of issues such as population growth, scarcity, and competition for some resources, related to processes of transition and change (Turner, 1979; Smith, 1984). The approach to the diet of a human group through the study of its dentition allows inferring types of food usually eaten and how they are combined, as well as techniques of food processing. The particular hardness derived from their physical and chemical characteristics have given them a low susceptibility to taphonomic degradation in archaeological contexts, allowing in many cases a differential conservation in comparison with other skeletal remains (Hillson, 1996).

In recent years, there have been several studies about diet and oral health of ancient population of Southern South America (Novellino & Guichón, 1994, 1997–1998, 1999; Kozameh & Barbosa, 1996; Novellino *et al.*, 1996, 2004; Barrientos, 1997, 1999; L'Heureax, 2000; L'Heureux, 1998, 2002; Novellino, 2002; Garcia Guraieb, 2006; Seldes, 2006; Aranda, 2007; Bernal *et al.*, 2007; Novellino & Gil, 2007; Luna, 2008; Luna

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& Aranda, 2010; Menéndez, 2010; Flensborg, 2011). However, it has not been systematically addressed in studies about lifestyle in populations of Central Argentina. There have been few statements about dental wear or dental hypoplasia in research articles (Bordach *et al.*, 1985; Bordach *et al.*, 1991; Barboza & Mendonça, 2004 quoted in Pastor, 2006) or archaeological reports (Fabra, 2000), but the topic has not been developed at regional scale until recent years (Fabra & González, 2008).

Human populations that inhabited valleys and hills of Córdoba province, in central Argentina –archaeologically known as 'Sierras Centrales' (González & Pérez Gollán, 1976)– had experienced changes in lifestyles and subsistence strategies from Early Holocene until the arrival of Spanish colonizers at the 16th century. Archaeological research shows continuous subsistence strategies based on hunting and gathering, from the first human populations, since approximately 10000 years BP., until early Late Holocene (Ameghino, 1885; Castellanos, 1943; González, 1960; Montes, 1960; D'Andrea & Nores, 1997; Laguens *et al.*, 2007; Pautassi, 2008; Sario, 2009). During this extensive period of time, availability of resources was influenced by various climatic changes, and populations developed subsistence strategies based on hunting – mainly of deer and guanaco – and gathering of wild fruits such as carob tree or *algarroba* (*Prosopis* sp.). Approximately 1500 years BP., the archaeological record suggests changes in subsistence strategies and technology that modified the lifestyle of these societies. Pottery and food production[1] were gradually incorporated – probably from populations of Northeast Argentina, from Chaco region – to the hunter and gathering traditions, as well as a village settlement pattern, that would have changed the way people lived and related to each other. There is not clear evidence about the role played by maize (*Zea mays*) agriculture, its relative importance, and chronology. Although the timing of agriculture adoption is not certain, isotopic evidence suggests a transitional stage through maize agriculture at around 1300–900 years BP., stage characterized by a diet based mainly on high consumption of faunal and C3 vegetal species (Laguens *et al.*, 2009). Recent paleodietary studies based on isotopic evidence are coincident with the archaeological record and suggest consumption of C3, C4, and CAM plants, as expected in mixed diets and regional differences for later periods (Laguens *et al.*, 2009).

Other study based on caries prevalence showed similar results to the ones obtained by isotopic evidence and suggest a mixed diet for later periods (Fabra & González, 2008). Whereas early samples from Middle Holocene had mean values that suggested a tendency towards greater consumption of C3, later samples did not reflect a clear incidence of maize in diet. Similar results were obtained for populations that inhabited Central-Western region of Argentina (Novellino *et al.*, 2004).

In this context, the aim of this paper is to analyze from a bioarchaeological perspective five non-specific dental indicators of stress, infectious, and degenerative diseases (Lukacs, 1989) – hypoplasia of dental enamel, dental caries, abscesses, antemortem teeth loss, dental calculus – and other markers as hypercementosis, dens in dens, and agenesis in order to study oral health of human populations that inhabited different environmental regions of Córdoba's province in two moments of Late Holocene – earlier late Holocene (ca. 2500–1500 years BP.) and later late Holocene (ca. 1500–400 years BP.) – that might reflect changes in subsistence strategies of these populations. We ask several questions to this study: How changes in subsistence strategies, sociopolitical organization, or development of new technologies were reflected in oral health? What was the impact of agriculture? Which were the most prevalent oral pathologies, and what were their causes? In which way did social circumscription and nucleation generated by demographic increase at later Late Holocene impact on oral health of these populations? Is there any regional, temporal, sex, or age difference in the prevalence of oral health markers? In the case of an affirmative answer, are these differences the result of changes in composition of diet, or might they be related to other causes?

The purpose of this paper is to evaluate and discuss these results in terms of subsistence strategies associated with different lifestyles. Particularly, we are interested, through the study of oral health, in: (i) analyzing spatial and temporal diversity in diet; (ii) determining which were the most prevalent infectious and degenerative oral pathologies considering their prevalence by sex, age, region, and chronology; and (iii) analyzing the influence of new practices such as food production and sedentary settlement, in the oral health of these populations.

Our hypothesis is that there will be changes in prevalence of different oral health markers between populations that developed a subsistence strategy based on hunting and gathering, and populations that incorporated agriculture, due to the consumption of food with high content of sugar and carbohydrates such as maize or pumpkins. We expect that the study of oral heath from a bioarchaeological perspective

[1] Remains of maize (*Zea mays*) and pumpkin (*Cucurbita* sp.) have been identified (Lopez, 2007)

would constitute a new and effective input that will increase the knowledge of the lifestyle of human populations that inhabited this region in Late Holocene.

The area of study

The central highlands and eastern lowlands of Córdoba province are located between 30–33º (S) latitude and 62–65º (W) longitude, occupying part of the territory of the provinces of Córdoba and San Luis, in Argentina (Figure 1). The area is characterized by three mountain chains, Sierras Grandes, Sierras Chicas, and Sierras Occidentales, that are separated by longitudinal valleys and high-altitude plains, or pampas (Capitanelli, 1979).

The subtropical location of the region generates dry winters and humid summers. There are two large wetlands in the Northern sector: Mar Chiquita Lagoon in the Northeast and Salinas Grandes in the Northwest. Regarding vegetation, a series of floral physiognomies are oriented in Northeastern–Southwestern bands, from the pasture lands in the steppe of the pampas in the Southwestern extreme, to low forests with dominance of acacias in a middle zone corresponding to the Espinal phytogeographical province – the ecotone between the Pampas and Chaco phytogeographical provinces – up to the stepped vegetation of the Chaco mountain forest, with shrubs and pasture lands at higher altitudes (Luti *et al.*, 1979; Cabido *et al.*, 2004). Northern portion of central highlands is characterized by the presence of

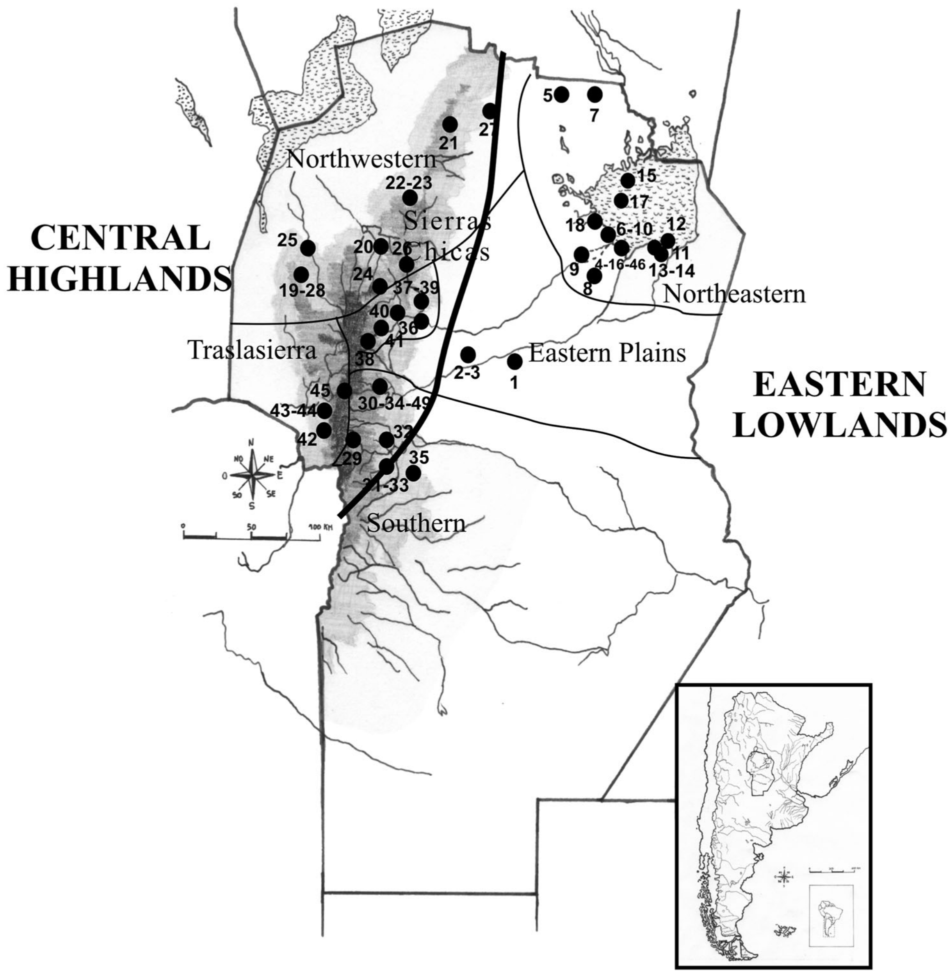

Figure 1. Central Highlands and eastern lowlands, Córdoba, Argentina. Archaeological sites considered in this study, grouped by subgeographical regions. Eastern Plains: 1) Costasacate, 2) Cosme, 3) Rincón. Northeastern: 4) El Diquecito, 5) Laguna de la Sal, 6) Campo Mare, 7) Pozo de las Ollas, 8) Marull, 9) La Para, 10) Ea. La Elisa, 11) Orihuela, 12) Isla Orihuela, 13) Colonia Muller, 14) Miramar, 15) Isla Tigre, 16) El Silencio, 17) El Mistolar, 18) La Fortuna, 46) Laguna del Plata. Northwestern: 19) Rosca Yaco, 20) Ongamira, 21) Cerro Colorado, 22) Nunsacat, 23) Ischilin, 24) San Esteban, 25) Charquina, 26) El Vado, 27) Rio Seco, 28) Guasapampa. South: 29) Yacanto, 30) Los Molinos and Potrero de Garay, 31) Quillinzo, 32) Va. Rumipal, 33) Banda Meridional del Lago, 34) Alto de las Conanas, 35) Paso Cabral. Sierras Chicas: 36) Parque Sarmiento, 37) La Granja, 38) Cuesta Blanca, 39) Cabana-Unquillo, 40) La Mandinga-Cosquin, 41) Ecoterra. Traslasierra: 42) Loma Bola, 43) Guasmara, 44) Va. de las Rosas, 45) Copina.

dry forests dominated by quebracho blanco (*Prosopis alba*), black locust (*Prosopis nigra*), mistol (*Ziziphus mistol*), pitch (*Cercidium praecox*) tintitaco (*Prosopis torquata*), and other trees and shrubs of smaller size. In the woods next to the depressions of the Salinas Grandes and Ambargasta is noticeable the presence of cardon (*Stetsonia coryne*). The shrubby stratum is the greatest coverage and consists of numerous species: jarilla (*Larrea divaricata*), lata (*Mimozyganthus carinatus*), piquillín (*Condalia microphylla*), atamisqui (*atamisquea emarginata*), tala churqui (*Celtis pallida*) abriboca (*Maytenus spinosa*), chañar (*Geoffroea decorticans*), among other shrubs. Between 500 and 1300 m above sea level develops the 'mountain forest' dominated by molle (*Bunk molleoides*) and coco (*coconut Fagara*), which are generally distributed as isolated individuals, and orco quebracho or quebracho of the mountains (*Schinopsis haenkeana*). The mountain forest shrub layer is characterized by the presence of the genus Acacia (*Acacia* sp.) and hawthorns (*Acacia caven*), tuscas (*Acacia aroma*), and apple trees of the field (*Ruprechtia apetala*).

On the other hand, eastern lowlands with altitudes ranging between 150 and 65 m above sea level have faint slopes crossed by several rivers in east–west direction. In its northern portion is the Mar Chiquita Lagoon, with an area reaching up to 2000 square kilometers, with several tributaries both from North to South, as the Rio Dulce. This is a huge salty lake located 64 m above sea level. The area offers, thus, the appearance of a steppe with islands of forest, marshes, and lakes with permanent or seasonal ponds. The original vegetation corresponds to the Espinal (Luti *et al*., 1979), a large ecotone between the provinces of Chaco and Pampas. The relics of the original vegetation consist of lowland forests, algarrobo blanco (*Prosopis alba*), and algarrobo negro (*Prosopis nigra*), as dominant species. In the northern sector, these species are often accompanied by quebracho blanco (*Aspidosperma*), mistol (*Ziziphus mistol*), itín (*Prosopis kuntzei*) and chañar (*Geoffroea decorticans*).

In terms of faunal communities, central highlands and eastern lowlands are located on the edge of the two South American biogeographical regions (the North and Eastern, and the South and Western, according to the divisions of Ruggiero *et al*., 1998). It is noted that its lower border merges approximately with the NW–SE arid diagonal, which has fluctuated over time (Páez *et al*., 2003). This zone presents a varied spectrum of prey animals, like guanaco (*Lama guanicoe*), pampas deer (*Ozotocerus bezoarticus*), corzuela (*Mazama guazoubira*), huemul (*Hippocamelus bisulcus*), peccary (*Tayassu tajacu*), as well as jaguar (*Felis concolor*), and Chacoan Mara (*Dolichotis salinicola*), quirquincho (*Chaetophractus* sp.), the ñandu's flightless bird (*Rhea americana*), and other smaller preys. The region of the Mar Chiquita lagoon has a wide variety of birds, including the group of waterfowl and rallidos, whose presence is very important. Also present are other species such as otter Creole (*Myocastor coypus*), water rat (*Holochilus brasiliensis*), aguará guazú (*Chrysocyon brachyurus*), black-legged fox (*Cerdocyon thous*), anteaters (*Myrmecophaga kittiwake*), and capybara (*Hydrochoeris hydrochaerys*) (Bucher and Abalos, 1979; Cabido *et al*. 2004). These vast plains are covered with forest vegetation, corresponding to the formation of transition Espinal (Luti *et al*., 1979).

Paleoenvironmental, archaeological, and ethnohistorical record

In the Early Holocene, as well as in the Late Pleistocene, a semi-arid and cold climate was dominant. These conditions gradually changed towards a subtropical climate, with higher temperature and humidity. Between 9000 and 4200 years BP. these climatic conditions favored the development of meadows in the high prairies of central highlands, and lagoons and swamps in the lowest areas (Piovano, 2005). At 6500 years BP. there are some perceptible changes in the archaeological record, with regard to technology (different type of projectile points, smaller than previous ones, suggests hunting of smaller animal resources, and the use of propellant or *atlatl*), and the use of landscape (higher occupancy of space, an increase of archaeological sites) accompanied by mild weather conditions. These changes were gradual and cumulative, these populations continued with hunting and gathering, and broadening the fauna and vegetables exploited.[2] An abrupt change towards dry and semi-arid conditions and high temperature occurred at 4200 years BP., lasting for 2000 years and causing the erosion and deflation of soil, deficit of water, decrease of lakes, development of the Salinas Grandes, and decrease in the volume of the large rivers. These changes suggest not only a different distribution of the food resources potentially exploited, but also changes in environmental offerings (Laguens *et al*., 2007). It seems that milling of seeds was an important activity, because of the quantity of polished lithic materials, flat mills of stone and storage pits, probably to storage seeds of *algarroba*. At around 3000 years BP., these changes were extended to all the region. Laguens (1999) suggests that these

[2] Food resources known from the archaeological record, in order of importance, were guanaco, deer, corzuela, peccary and quirquincho (small armadillo), in addition to the rhea represented by egg shells. Human diets may also have included beans and other wild fruits like chañar (*Geoffrea decorticans*), mistol (*Zyzyphus mistol*) tala (*Celtis tala*), algarrobo (*Prosopis* sp.), and acacia (Laguens & Bonnin, 1987).

archaeological evidences must represent a success in resource use and exploitation that could leave to a population increase, or can indicate long-term conservative strategies due to warmer and arid–semi-arid climatic condition, that lasted 2000 years.

As mentioned above, pottery and food production were incorporated around 1500 years BP. Populations turned towards a mixed economy based on hunting and gathering, and agriculture, as a complementary strategy, did not surpass 50% of diet (Laguens, 1999). This strategy of mixed economy was part of an organization centered on risk-avoidance in an environmental context of uncertainty (Laguens, 1999). A regional model of resource exploitation based on Laguens' research at Copabacaba valley, in the Northwestern region of the province of Córdoba, has been proposed. This model suggests that these populations exploited different ecological floors, from hills to plains (Laguens, 1999). This model was confirmed for other regions (Pastor, 2006; Pastor & Berberian, 2007; Medina *et al*., 2009). This complementary strategy seems to be a long-term tradition in this region, based on archaeological record of Intihuasi Cave, from Early Holocene, which shows exploitation of animal species of different ecological floors (González, 1960). It is remarkable that food production did not alter the previous ways of obtaining food; its production was adjusted to the hunter-gathering logic based on complementary exploitation of differential resources of Chaco Hills and grassland vegetation of Córdoba's high prairies (Luti *et al*., 1979; Cabido *et al*., 2004). These innovations were not adopted at the same time in the whole geographic space, but they would have created a new way of life for these populations that was going to differ from the previous one and would have been adopted across the region.

Various indicators suggest that for the period 1100–1400 AD there was an interval characterized by wet weather conditions, with a wetter rainfall regime or similar to the current (Carignano, 1997), known worldwide as 'Medieval Climatic Anomaly'. Archaeological evidence suggests for various sites in the region more benign weather conditions, with a marked increase environmental sustainability (Laguens & Bonnin, 1987). This range corresponds to an improved climate in the Midwest, recorded by an incipient soil development, expansion of the lake and river systems and the formation of swamps in the lowlands (Carignano, 1997). Another event, known worldwide as the 'Little Ice Age', from the late 14th to the mid-19th century, involved according to available evidence climatic deterioration towards drier conditions and colder than those observed herein. In the central region of Argentina this episode was not homogeneous, but consisted of two cold pulses separated by an intervening period of benign weather conditions, similar to today, and even a bit more humid (Cioccale, 1999). The first pulse occurred between the early 15th and late 16th century, coinciding with a decline in indigenous system conditions characterized by population stress produced by a decrease in environmental sustainability (Laguens, 1993). The second pulse would have occurred since the beginning of the 18th and 19th centuries. The historical data reveals significant rainfall deficit during the 18th and early 19th century, with large interannual variations and extreme cycles of drought and moisture mainly affected the north region of Córdoba. There was a marked decrease in the flora, species were replaced by western Chaco, in equilibrium with drier environmental conditions (Bonnin *et al*.,1987). Erosion was reactivated in several areas, retracts the Laguna Mar Chiquita with levels below those recorded in the 20th century and formed salt flats that remain to this day in the Northwest of the province. This change altered the landscape and vegetation distribution and was one of the main factors that regulated human activities over the last 1000 years (Cioccale, 1999). Laguens and Bonnin (2009) note that for the moments before the Spanish conquest, population had reached the limits of the carrying capacity of the environment, and societies would have been in a situation of crisis and conflict, not only their lifestyles but also their organization and traditional structures of power and authority. It would have produced political restructuring processes, alliances between peoples and strengthening of the authority through ritual, which could not prosper due to forced cultural change meant the imposition of the colonial regime.

Ethnohistorical research also show separation processes for political structures, called fission. When a population reaches the maximum support that environment can provide, groups can divide, as an adaptive strategy, into smaller ones, but continue to maintain relationships, many of which could be strengthened through ritual practices such as joints or gathering wild fruits, or even in case of war. Through some testimonies from documentary sources, it can be perceived that these processes had occurred before the Spanish arrived.

The archaeological record of regional differenciation

Archaeological record allows us to infer an increasing process of regional differentiation at around 2000–1500 years BP., probably due to diverse adaptations to the environment made by these populations and development of different technological styles. This process led to political autonomy and identity associated with different geopolitical units, just as it can be deduced from analysis of the ethnohistorical documentation of the 16th and 17th centuries (Laguens, 1993, 1999).

Considering these developing and function of archaeological evidence, six regions have been proposed by the characteristics of their archaeological record could represent the different adaptations and lifestyles of these communities: Northwestern, Sierras Chicas, Traslasierra, and Southern region, located at central highlands, and Northeastern and Eastern Plains at eastern lowlands (see Figure 1). We want to point out briefly the principal differences and similarities – according to the archaeological record – of communities that inhabited different environments of this region, which could indicate different adaptations terms of subsistence strategies by these populations, or ways of differentiating between the different groups, following Laguens and Bonnin (2009).

Traslasierra region is a vast valley, crossed by two major watersheds. Archaeological sites are located in relation to major water courses and is common to find pottery anthropomorphic figurines, vessels with incised decoration of smooth lines and points, stone tools and projectile points, as well as burial sites. Dwellings were semisubterranean, known as 'pit houses'. The northern part of Valle de Traslasierra has certain similarities to the Northwestern region: presence of underground tanks and jars and the presence of ceramic impression of straw; and the south of the valley possess in common with Sierras Chicas, Southern, and Eastern plains, the presence of anthropomorphic figurines, pottery incised, and possible evidence of pit houses.

Moreover, the Northwestern region is located between the Salinas Grandes at the north, and along the foothills of the Sierras Chicas to the south. Archaeologically, this region has been characterized by finding sites with high concentration of ceramic and stone, and large concentrations of underground deposits of terracotta or furnaces. These findings may correspond to large settlements or villages. There is no evidence of pit houses. There have been numerous archaeological sites with rock art. The pottery has little decoration, with imprints of basketry. The lithic material is abundant, with little variability in the forms.

The Northeast region includes plains that converge in the North and Northeast to the natural depression of the salt lake of Mar Chiquita Lagoon. The archaeological research on this area is scarce. As in the Northwestern region, there is no evidence of semisubterranean houses. Dwellings had taken advantage of proximity to the lake or places near streams, high in the field or the canyons. Lithic tools are scarce compare with other technologies, like pottery. There are high amounts of underground furnaces. Pottery production manifests painted vessels, and vessels with nets and baskets imprint. No anthropomorphic pottery figurines have been found and no evidence of pit houses.

The region called Sierras Chicas is located in the eastern and western slopes of the highlands and southern Punilla Valley, and it is characterized by archaeological sites located near water courses, in lands suitable for agriculture, as well as rock shelters in the high plains. Material culture is characterized by work in bone (projectile points, spoons, and spatulas), and variety in vessels forms and decoration, as well as pottery figurines.

Finally, Eastern plains and Southern regions are characterized by sites located at the bottom of the valleys, near water courses. The sites can be defined as locations of different sizes, forming villages of pit houses. Material culture shows a notoriously wide variety of instruments; pottery production is abundant, being characteristic geometric decoration with rhythmic grooves and in some cases the presence imprinting of straw at the base of the pots, anthropomorphic and zoomorphic pottery figurines, instruments made of bone and its investment in decoration is higher than other regions. The stone tools are also very varied, often the discovery of stone axes, mortars in granite, as well as heads of weapons made of quartz or quartzite from the mountains.

Mortuary practices also show differences between different subregions – Northwest/Southern/Traslasierra and Northeast/Eastern plains/Sierras Chicas – suggesting personal and/or social differentiation among societies (Fabra *et al.*, 2009).

Materials and methods

The sample

In this study, we analyzed permanent teeth of 83 adults individuals, which came from 47 archaeological sites located both in central hills and high pampas, valleys as well as oriental plains and the Mar Chiquita Lagoon, in Northeast (Figure 1). These samples belong to 47 male, 32 female, and four from undetermined sex adults, with anterior and posterior dentition that were 50% complete or above. Twenty one of the samples were from burial sites excavated during archaeological rescues from 1999 to 2009 and are stored at the Anthropological Museum (Museo de Antropología) of the city of Córdoba, as well as 36 samples that correspond to its archaeological collection. The remaining samples belong to different public museums of Córdoba: Museo Histórico Municipal La Para (16 samples from Northeastern region), Museo 'Anibal Montes' of Miramar (four samples from Northeastern region), Museo Provincial Arqueológico of Río Segundo (five samples from Oriental plains region), Museo Histórico y Arqueológico of Potrero de Garay (one sample from Southern region), and Museo Estrella de Piedra of Villa Rumipal (one sample from Southern region). In cases where samples were obtained by archaeological rescues (El Diquecito, Estancia La Elisa, Isla Orihuela, Orihuela, Colonia Muller, Nunsacat, San Esteban, El Vado, Banda Meridional del Lago, La Granja, Ecoterra, Loma Bola, and Guasmara sites), we had information about mortuary practices and associated archaeological materials that allowed us to infer their relative chronology before performing ^{14}C dating. The remaining samples were not obtained from systematic archaeological surveys, so there was no contextual information, only references about burial or site geographic location.

For each individual, we considered age-at-death and sex following methodological standards presented by Buikstra and Ubelaker (1994), considering three age categories: young adult −20–35 years old, middle adult −35–50 years old, and old adults −50+ years old.

Regarding to samples chronology, we considered: (i) ^{14}C dating measures by AMS of 26 individuals that range between 2156 ± 60 and 520 ± 15 ^{14}C years BP. (Table 1); (ii) information about chronology of artificial cranial deformation in other regions, as a chronological relative indicator −6 individuals that had oblique tabular cranial deformation were considered of earlier late Holocene (elh) – ~ 2500–1500 years B.P. –, whereas that 15 individuals that had tabular planolambdic erect cranial deformation were considered of later late Holocene (llh) – ~ 1500–500 years BP –; and (iii) contextual information about archaeological sites. In some cases in which we did not have contextual information about samples, we considered them as belonging to late Holocene (lh).

With regard to teeth condition, we registered 1144 teeth completely developed, in occlusion. This amount represents 55.38% of total observed teeth, since the rest corresponded to pieces whose absence is inferred as post-mortem, with no socket reabsorption (27.87%) or antemortem teeth loss (11.96%). With a minor percent, we recorded: (i) teeth losses by undetermined cause due to poor socket preservation or presence of abscesses; (ii) damaged teeth where no dental marker can be registered; and (iii) unerupted teeth.

Table 1. ^{14}C radiocarbon information of 26 samples considered in this study

Region	Archaeological site	Laboratory code	Sample	Age	Sex	^{14}C age BP
NW	(26) El Vado	MTC12808	EV08 I1	MA	F	2156 ± 86
NE	(13) Colonia Muller	UCI 39102	CMuller I1	A	F	1585 ± 15
SCh	(37) La Granja	UCI 22282	LG98 I1	MA	F	1280 ± 20
NE	(4) El Diquecito	MTC13247	ED08 CE, I1	MA	M	1192 ± 40
SCh	(38) Cuesta Blanca	MTC 13249	CBI1	YA	M	1080 ± 40
NE	(11) Orihuela	UCI 39101	OrihI1	YA	F	1045 ± 15
S	(30) Los Molinos	MTC13246	E8/53	A	M	995 ± 161
S	(30) Los Molinos	MTC13251	E3/41	A	F	981 ± 41
S	(31) Rio III Quillinzo	MTC13245	29-103	A	M	975 ± 38
NW	(24) San Esteban	UCI 39103	SE06 I1	YA	F	965 ± 15
TR	(42) Loma Bola	MTC12806	LB07 1A	MA	M	954 ± 85
NE	(4) El Diquecito	MTC 13214	ED08 CL, I1	A	M	937 ± 150
TR	(43) Guasmara	UCI 22281	G98I2	YA	M	920 ± 20
S	(30) Los Molinos	MTC13215	E6/56	A	M	881 ± 150
NE	(4) El Diquecito	MTC12807	ED08 CB I2	YA	M	750 ± 85
NW	(19) Rosca Yaco	MTC13252	RYaco I1	MA	M	705 ± 131
S	(33) Banda Meridional del Lago	UCI 39104	BML I1	MA	F	695 ± 20
NE	(17) El Mistolar	MTC12805	MIR1 (zmjs 5)	A	M	690 ± 85
TR	(45) Copina	MTC13248	Copina1984 N2	A	M	680 ± 40
NW	(21) Cerro Colorado	MTC 13216	A105-45-42	A	M	664 ± 150
NE	(5) Lag. de la Sal	MTC13255	PO01LagSal	MA	M	623 ± 42
NW	(23) Ischilin	MTC13256	Ischilin I1	A	M	459 ± 40
NW	(25) Charquina	MTC13253	A113 11	A	M	445 ± 38
S	(30) Los Molinos	MTC13254	E9	A	M	420 ± 41
NW	(22) Nunsacat	MTC13250	CopNunsI2	MA	M	387 ± 41
EP	(3) Rincon II	UCI 22285	RIIS1 II2607	MD	F	520 ± 15

References: Region: S (southern), NE (northeastern), NO (northwestern), SCh (Sierras Chicas), TR (Traslasierra), EP (Eastern Plains); Archaeological site: number between parenthesis indicates the reference in the map; Laboratory Code: MTC (Graduate School of Frontier Sciences, University of Tokio), UCI (Earth System Science Dept., University of Irving); Age: A (adult), MA (middle adult), YA (young adult); sex: F (female), M (male).

Methodology

In order to characterize diet and oral health of these populations, we considered five non-specific dental markers of stress, infectious, and degenerative disease.

Hypoplasia of dental enamel is considered as permanent defect that results from arrested enamel production during tooth development. We excluded lineal hypoplasia that only occurred in one tooth, because it can be the result of local stress (trauma). Linear enamel hypoplasias were visually inspected, scored for each individual mandible canine (Barrientos, 1999).

We also considered some pathologies derived from developmental disorders, such as hypercementosis – excessive increase in cement, dens in dens – invagination of dental tissues (enamel, dentine and in occasions, pulp), and agenesis – reduction of the number of teeth.

We considered dental caries, abscesses, and antemortem tooth loss (AMTL) as infectious diseases. Caries can be defined as an infectious disease process stemming of demineralization of dental tissue by organic acids produced by oral bacteria (Larsen, 1997). Dental caries were recorded as presence/absence, considering lesion location, size, and severity following Buikstra and Ubelaker (1994). Rates of dental caries were defined as the number of carious teeth divided by the number of observable teeth.

Regarding to abscesses, we registered presence/ absence, location, and morphology following Clarke (1990); Clarke and Hirsch (1991); Buikstra and Ubelaker (1994), and L'Heureux (1998). Rates of abscesses were calculated dividing number of abscesses by the total number of sockets.

In this paper, we call AMTL to sockets in process of reabsorption, considering degree of bone remodeling, as well as sockets completely reabsorbed, following Buikstra and Ubelaker (1994), and Lukacs (1989). ATML can steam from a variety of etiological pathways, such as advanced dental caries, advanced dental wear, nutritional deficiencies, or trauma (Ortner, 2003). ATML rates were calculated dividing the number of antemortem teeth losses by the total number of sockets.

Dental calculus is a degenerative disease which results from mineralization of living dental plaque deposits (Lukacs, 1989; Greene *et al.*, 2005). They were recorded as presence/ absence, and their rate was defined by the number of affected teeth divided by the total number of observable teeth.

Intraobserver error and statistical analysis

Assessment of intraobserver error was performed using a subsample of 10 individuals ($n = 320$ teeth). To avoid interobserver error, all the registers were made by one of the authors (CG). We registered five nominal dichotomous variables (dental development, presence/ absence of abscesses, hypoplasias, perls, and other pathologies) and six continuous variables (presence of teeth, caries – part of the piece, caries – location, caries – quantity, abscesses – location, abscesses – type). These variables were registered twice for each tooth, leaving 15 days of interval between each observation to guarantee independence of observations. The degree of intraobserver error was evaluated by means of Kappa index (K; Cohen, 1960) for nominal variables, intraclass correlation coefficient (ICC; Shrout & Fleiss, 1979), and analysis of variance (ANOVA) of repeated measures for continuous variables. Intraclass correlation analysis allows evaluating degree of agreement between series. Kappa index allows evaluation of the degree of agreement between different series of observations above the expected by random. Moreover, ANOVA of repeated measures allows estimation of the existence of significant differences between two series of observations.

Finally, we calculated prevalence by sex, age, geographic subregion, and chronological period. We applied Chi-square (X^2) to test statistical significance of differences observed.

Results

The results of intraobserver error by means of Kappa index (K) for nominal dichotomous variables show a very good agreement, following Landis and Koch (1977) scale – between 0.8 and 1. Otherwise, by ICC, degree of agreement for continuous variables was excellent (>0.74), following Fleiss (1981). Results of ANOVA were not significant; therefore, they indicate absence of systematic errors in registering variables in different series of observations.

If we considered teeth condition in terms of sex, we observed a similar pattern to the one described above (43.66% teeth completely developed in females, and 63.60% in males). It is remarkable the higher prevalence of antemortem losses in females (16.29% against 8.58% in males).

Taking into account the general prevalence for the sample as a whole, we observed low frequencies of dental caries (117 teeth infected in a total of 1144, representing 10.27%), abscesses (189 in a total of 2008 sockets, representing 16.52%), dental enamel hypoplasia (124 teeth, in a total of 1144, representing 10.84%), and AMTL (275 in a total of 2008 sockets, representing 13.69%). Perls (3 in a total of 1144 teeth, representing 0.26%) and other pathologies (34 in a total of 1144, representing 2.97%) were even less frequent. On the contrary, dental calculus (65.20%) was the most common pathology observed in the sample (Table 2).

Once we considerer general prevalence for the sample as a whole, we were interested in inquiring about the prevalence of different dental markers considering age, sex, chronology, and geographic origin of each individual. In general, we observed that dental pathologies are more frequent in middle-aged and old adults, with the exception of dental hypoplasia, which is more prevalent in young adults (Table 2). If we consider prevalence by sex, we observed similar rates for males and females in abscesses and calculus, but differences in rates of caries and AMTL (higher prevalence in females) and dental enamel hypoplasia (higher prevalence in males). If we consider prevalence by chronology, most dental pathologies were more frequent in later late Holocene or late Holocene, with the exception of dental hypoplasias, more prevalent in earlier late Holocene. Calculus had a similar prevalence during the whole late Holocene. Moreover, if we consider prevalence by geographical region, caries and AMTL were more prevalent in Northeastern, while in Traslasierra the most prevalent dental pathologies were hypoplasia, dental calculus, and caries, with a similar frequency to the one in Northeastern. Abscesses were more prevalent in Sierras Chicas.

Considering prevalence of each separate dental marker, we observed that caries were more frequent in old adult females, from late or later late Holocene from Northeastern and Traslasierra region. Caries appeared to be more present in molars and premolars, and most of the caries appeared to have affected pulp cavity (43%) followed by crown, neck, and root caries (17%).

A similar pattern was observed for AMTL, other infectious pathology. It was more prevalent in middle aged female adults from late or later late Holocene from Northeastern and Northwestern region.

Unlike the pattern describe above for caries and AMTL, abscesses were more prevalent in old male adults of earlier late Holocene from Sierras Chicas. They were associated with alveolar bone of posterior teeth, principally molars.

Dental enamel hypoplasia presented a particular pattern, different from the one observed for caries. Hypoplasia was more prevalent in young male adults from later late Holocene from Traslasierra region.

Calculus appeared as a degenerative pathology with similar rates in males and females at the beginning and at the later moments of Late Holocene. They were more frequent in Eastern plains and Traslasierra region. Regarding their location, they were more prevalent in molars and premolars.

Regarding other pathologies derived from developmental disorders, it is interesting to note the high rates of agenesis of third molar, especially in males – 11 out of 83 individuals presented agenesis, representing 13.25%.

Finally, we applied Chi-square (X^2) to test if differences observed in the prevalence of different markers for sex, age, chronology, or geographical provenance were statistically significant or not (Table 3). Considering the sample as a whole, only dental enamel hypoplasia and calculus presented statistically significant differences by chronology, being more prevalent on later late Holocene. Abscesses showed significant differences by age, being more prevalent in old adults.

In order to refine the analysis, we consider each subgeographical region independently: we observed that differences in prevalence of dental enamel hypoplasia were statistically significant at Northeastern and Traslasierra regions, in later late Holocene, and in Traslasierra, more prevalent in males. Calculus was also more prevalent in Northeastern region, in later late Holocene. Differences in abscesses rates were significant in middle age adults from Traslasierra region.

Discussion

Taking into account the general prevalence for the sample as a whole, low frequencies of dental caries, abscesses, and dental enamel hypoplasia are coincident with values observed for populations with mixed or a hunter-gathering subsistence strategy, following Lukacs (1989), and Turner (1979).

In the case of caries, we observed a higher incidence of this pathology in old adult females from later late Holocene, mainly from Northeastern and Traslasierra region; however, these differences were not statistically significant. Caries appeared to be more present in molars and premolars, and most of the caries appeared to have affected pulp cavity. We associate this pattern not to dietary but to high dental wear rates on occlusal surface, which had favored caries development on pulp cavity. This infectious pathology is associated with the consumption of sugar-rich foods, probably maize. Both in highlands and lowlands of Córdoba, archaeological knowledge of pre-hispanic use of cultigens and wild fruits is currently limited. Agriculture practices are inferred through indirect indicators as pottery or information obtained from ethnohistorical documents[3]

[3] Sotelo de Narvaez's chronicle (1583), Priest Barzana's letters (1594) and Relación Anónima (1573) among others (quoted in Laguens & Bonnin, 2009).

Table 2. Prevalence of non-specific dental markers of stress, infectious and degenerative diseases

	Caries		Abscesses		AMTL		Dental enamel Hypoplasia		Calculus		Perls		**Other**	
	Prevalence loci*	(% affected)	Prevalence loci**	(% affected)	Prevalence loci**	(% affected)	Prevalence loci**	(% affected)	Prevalence loci*	(% affected)	Prevalence loci*	(% affected)	Prevalence loci*	(% affected)
By age														
Young adults	14/250	5.6%	10/352	2.84%	33/352	9.37%	42/250	16.80%	145/250	58%	1/250	0.4%	6/250	2.04%
Middle adults	35/324	10.80%	44/436	10.09%	100/436	22.93%	43/324	13.27%	285/324	87.96%	0/324	0%	9/324	2.77%
Old adults	20/99	20.20%	36/224	16.07%	41/224	18.30%	4/99	4.04%	45/99	45.45%	0/99	0%	1/99	1.01%
Adults	48/460	10.43%	99/996	9.93%	101/996	10.14%	34/460	7.39%	268/460	58.26%	0/460	0%	18/460	3.91%
By sex														
Female	54/431	12.53%	68/823	8.26%	126/823	15.31%	42/431	9.74%	281/431	65.20%	0/431	0%	9/431	2.08%
Male	54/626	8.62%	102/1058	9.64%	131/1058	12.38%	69/626	11.02%	417/626	66.61%	1/626	0.15%	23/626	3.67%
Undetermined	9/76	11.84%	19/127	14.96%	18/127	14.17%	12/76	15.79%	45/76	59.21%	0/76	0%	2/76	2.63%
By chronology														
E. late Hol.	16/170	9.41%	22/300	7.33%	14/300	4.66%	17/170	10%	126/170	74.11%	0/170	0%	11/170	6.47%
L. late Hol.	43/417	10.31%	31/552	5.61%	61/552	14.62%	76/417	18.22%	309/417	74.10%	1/417	0.23%	11/417	2.64%
Late Hol.	58/546	10.62%	136/1156	11.76%	200/1156	17.30%	30/546	5.49%	308/546	56.41%	0/546	0%	12/308	2.19%
By geographic region														
Northeastern	43/384	11.19%	74/779	9.30%	158/779	19.87%	26/384	7.03%	231/384	60.93%	0/384	0%	11/384	2.60%
Northwestern	11/148	7.43%	24/279	8.60%	43/279	15.41%	18/148	12.16%	83/148	56.08%	0/148	0%	6/148	4.05%
Oriental Plains	5/80	6.25%	11/222	7.69%	10/222	4.89%	22/80	15%	63/80	78.75%	0/80	0%	2/80	2.50%
Sierras Chicas	10/101	9.90%	27/206	13.10%	11/206	5.33%	7/101	6.93%	55/101	54.45%	0/101	0%	5/101	4.95%
Southern	27/248	10.88%	33/382	8.36%	46/382	12.04%	28/248	11.29%	170/248	68.54%	0/248	0%	6/248	2.41%
Traslasierra	21/183	11.47%	20/219	9.13%	10/219	4.56%	32/183	17.48%	141/183	77.04%	3/183	1.63%	4/183	2.18%
TOTAL	*117/1144*	*10.27%*	*189/2008*	*16.52%*	*275/2008*	*13.69%*	*124/1144*	*10.84%*	*794/1144*	*65.20%*	*3/1144*	*0.26%*	*34/1144*	*2.97%*

*number of affected teeth/total number of observable teeth
**number of affected teeth/total number of sockets

Table 3. Chi-square analysis (only statistically significant results showed) by individuals

	Dental enamel hypoplasia				Calculus				Abscesses			
	Absence/Presence*	X2	Prob.	gl	Absence/Presence*	X2	Prob.	gl	Absence/Presence*	X2	Prob.	gl
Considering the whole sample												
By chronology												
Early late Holocene	7/5				4/8				-	-	-	-
Later late Holocene	8/15				3/20				-	-	-	-
Total	20/33	9.462	0.009	2	27/56	5.808	0.055	2	-	-	-	-
By age												
Young adults	-	-	-	-	-	-	-	-	8/6			
Middle adults	-	-	-	-	-	-	-	-	8/10			
Old adults	-	-	-	-	-	-	-	-	1/8			
Adults	-	-	-	-	-	-	-	-	10/32			
Total	-	-	-	-	-	-	-	-	27/56	8.836	0.039	3
Considering geographic region												
Northeastern												
By chronology												
Early late Holocene	1/1				0/2				-	-	-	-
Later late Holocene	¼				0/5				-	-	-	-
Late Holocene	23/4						14/13		-	-	-	-
Total	25/9	9.814	0.007	2	14/20	6.17	0.046	2	-	-	-	-
Traslasierra												
By chronology												
Later late Holocene	0/5				-	-	-	-	-	-	-	-
Late Holocene	2/1				-	-	-	-	-	-	-	-
Total	2/6	4.444	0.035	1	-	-	-	-	-	-	-	-
By sex												
Female	2/1				-	-	-	-	-	-	-	-
Male	0/5				-	-	-	-	-	-	-	-
Total	2/6	4.444	0.035	1	-	-	-	-	-	-	-	-
By age												
Young adults	-	-	-	-	-	-	-	-	2/0			
Middle adults	-	-	-	-	-	-	-	-	0/3			
Adults	-	-	-	-	-	-	-	-	0/3			
Total	-	-	-	-	-	-	-	-	2/6	8	0.018	2

*number of individuals who had not been affected/number of affected individuals

which mentioned that food production would have been probably introduced by mid first millennium of the Christian era.[4] According to these documents, food production could be performed at small farms near houses, or scattered in the hills, far away from the villages. More recently, archaeobotanical research documented macro-remains of common bean (*Phaseolus vulgaris aff. var. vulgaris*) (López, 2005, 2007) maize (*Zea mays*), lima bean (*Phaseolus cf. P. lunatus*) and algarrobo seeds (*Prosopis cf. P. nigra*), and micro-remains of maize, squash (*Cucurbita sp.*), chañar (*Geoffroea decorticans*) and algarrobo (*Prosopis sp.*) (Medina *et al.*, 2009).

Previous studies based on isotopic evidence (Laguens *et al.*, 2009) had suggested that: (i) agriculture –presumably from maize or *cucurbita*– would have been incorporated partially to diet at later late Holocene and (ii) its incidence would not have been a contemporary phenomenon in all subgeographical regions. According to isotopic values, in Sierras Chicas and Traslasierra, food production would have been incorporated some time before the Spanish conquest, much later than in Northeastern or Eastern plains regions, and always as a complementary practice to hunter and gathering. Thus, high prevalence of caries at Traslasierra region could be explained not for maize consumption but for other vegetable resources, like legumes of *Prosopis* gender, which have higher caloric values because of its content of carbohydrate –particularly sugars and starch.[5] Similar results from human groups with hunter-gatherer strategies that inhabited the Pampa region in Argentina were reported by L'Heureux (1998, 2002) and for the Cuyo region by Novellino *et al.* (2004). Moreover, in Southern or Northeastern regions

[4] The discovery of maize phytoliths (*Zea mays*) in a skeleton dated ^{14}C 2466 ± 51 years BP has been interpreted as an early evidence of the circulation and consumption of these cultigens in the region (Pastor, 2008). However, δ^{13}C value (−16.1%) published in the same article would suggest that crops didn't have a significant impact on diet.

[5] Prosopis has 25-28% glucose, 11–17 % starch, 7-11% proteins, and 3.95% fat (Burkart, 1943; Cano, 1988).

of Córdoba, where isotopic evidence showed average values that suggested a tendency to a consumption of C4 plants, we could interpret the presence of caries due to the intake of maize, although we do not reject *Prosopis* consumption as an important part of diet. Even in late 17th century, *algarroba* gathering and consumption was an important resource in times of drought and scarcity for indigenous societies (Castro Olañeta, 2006).

Another dental pathology that presented higher incidence in young adult males from later late Holocene was dental enamel hypoplasia. When considering the statistical significance of these differences, they were significant in Northeastern (more prevalent in later late Holocene) and Traslasierra region (more prevalent in males from later late Holocene). Regarding the relationship between age-at-death and presence of hypoplasia in young male adults, it must be related to two factors: (i) differences between sex could be related to differential feeding or resource consumption, or it may reflect similar levels of exposure to stress, resulting in higher mortality in female population and a higher frequency of dental enamel hypoplasia among male survivors (Lukacs, 1992; Garcia Guraieb, 2006), or (ii) high rates of dental wear in middle age and old adults that would diminish crown height, hinding record, and visualization of dental hypoplasia (King *et al.*, 2005).

Also, the higher incidence in young males would indicate episodes of metabolic-systemic stress which would have led to a decline in the quality of life, in centuries prior to the Spanish conquest. These episodes were possibly linked to: (i) dietary changes, and/or (ii) reduced availability of resources.

At later late Holocene, around 1000 years BP., dry and arid conditions slightly modified towards sub-humid and temperate ones – period known as *Medieval Climatic Anomaly* from 900 to 600 years B.P. (Riccardi, 1995). At global scale, another climatic change of equal magnitude to MCA took place – *Little Ice Age* from 600 until 200 years B.P. (Riccardi, 1995), but with reverse implications: in province of Córdoba, it was characterized by aridification, arid/semi-arid cold conditions, and decrease in rainfall and water deficit. Laguens and Bonnin (1987) mentioned that this change coincided with significant deterioration of the indigenous system: pre-existing crisis of indigenous societies, previous to the Spanish conquest, was characterized by population stress produced by decrease of environmental sustainability (Laguens, 1993). The archaeological record suggests that, before the Spanish conquest, human societies would have been subject to a number of changes or pressures of environment (gradual aridity product of Little Ice Age), demographic (population growth), and social pressures (greater circumscription and nucleation). The increasing pressure on resources and a circumscribed environment may have favored farm intensification. All these changes would have impacted in mode and living conditions of indigenous societies settled on this region.

If we look at chronological differences in dental markers rates, we observe that AMTL and calculus present higher incidence in later late Holocene. In the case of calculus, the difference was statistically significant considering chronology (more frequent in later late Holocene) and region (more frequent in Northeastern region). Increases in these pathologies are related to caries (Lukacs, 1992; Cuccina & Tiesler, 2003). Calcification of dental plaque could be related to a diet rich in starch and proteins (Litleton & Frholich, 1993).

Regarding abscesses, they were more frequent in early late Holocene, but their prevalence was not statistically significant. The difference was significant for old adults, considering the whole sample, especially in Traslasierra region. This pathology is associated to high rates of occlusal dental wear, because it would favor pulp-socket infections that led to abscesses development. High rates of dental wear have been associated with hunter-gatherer populations (Molnar, 1971; Hinton, 1981; Smith, 1984; Jurmain, 1990). We have not conclude yet our studies about dental wear in this populations, but we consider abscesses rates according to the expected values, considering that at early late Holocene this populations would have had a subsistence strategy based on hunter and gathering.

To summarize, we mention the main contributions of this work, with respect to diet and health,

- The moderate frequency of caries, abscesses, AMTL and hypoplasia are consistent with the expected values for populations of hunter-gatherer or mixed economy, which incorporated farming as a livelihood strategy to traditional hunter-gathering strategies.
- The consumption of cariogenic foods would go back to the beginning of the Late Holocene, with a slight increase towards later late Holocene.
- The moderate values of caries recorded in early late Holocene may correspond to the consumption of wild plant resources, mainly the fruit of the carob and chañar trees – which have high levels of carbohydrates and sugars –, whereas for later Holocene times the presence of caries would result from the incorporation of cultivated crops, such as corn, but always complementary to the hunting and gathering strategies.

- The infectious, degenerative, and metabolic diseases differed in their incidence in different regions.
- The highest incidence of hypoplasia in Traslasierra, Eastern plains, and Northwestern regions may be due to several external and internal factors that have affected the health status of these populations, such as environmental changes or the availability of resources, population growth, changes in diet, among others.
- Northeastern, Northwestern, and Traslasierra regions have the highest frequencies of all diseases, with a strong presence from the early Late Holocene. We believe that this continuity over time and this increase in the prevalence of certain diseases to moments before the Spanish conquest can refer to the increased consumption of cariogenic foods.
- The analysis of enamel hypoplasia suggests that populations suffered a decline in health standards in the final moments of the late Holocene. The most affected by episodes of stress would have been the young and middle adults throughout the study area, and especially those who inhabited the Northeastern subregion, and males from Traslasierra.
- The difference observed between young and older adults could indicate differential mortality levels, being younger individuals the socially disadvantaged, and who therefore did not survive to adulthood.

We believe, based on the joint evaluation of the results obtained from the analysis of dental biomarkers, isotopic and archaeological evidence, that food production in this region can be understood as a complementary economic strategy to hunter-gathering The gathering of wild fruits could be thought as a practice with a long continuity over time, important since at least the initial moments of the late Holocene. Results obtained in this work could provide new insights on the mode and quality of life – especially regarding diet and nutrition – of human populations that inhabited these regions during late Holocene. All the processes mentioned above would have impacted in these populations, causing a decline in general conditions, compared to available evidence for early late Holocene. Future studies about stable isotopes, dental macro and microwear, as well as phytoliths analysis in dental calculus (Lalueza Fox *et al*., 1996) will broaden and improve the inferences made from the markers used in this work.

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