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HEAD COMBS FOR DELOUSING IN ANCIENT ARICAN POPULATIONS: SCRATCHING FOR THE EVIDENCE

PEINES PARA EL DESPIOJAMIENTO EN LAS ANTIGUAS POBLACIONES DE ARICA: RASCANDO LA EVIDENCIA

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We explore the hypothesis that small combs coming from AZ71, PLM4, PLM6, and CAM8 archaeological sites in Northern Chile were produced specifically to remove head lice and their nits/eggs. Andean combs (N=41) housed at the Museo Arqueológico de la Universidad de Tarapacá, Arica, dating from 240 to 800 BP were studied microscopically for signs of usage. The presence of fibers, head lice (*Pediculus humanus capitis*), their eggs and nits (which are the empty eggs without the embryo) were systematically noted as the combs were observed. A total of 23/41 archaeological combs (56%) were positive for *P. humanus capitis* evidenced by lice, eggs, and/or nits. On those combs positive for *P. humanus capitis* 17.4% (4/23) presented human hair embedded in the tines. No other inclusions such as textile-related fibers were present to associate the combs with use in textile production (0/41). These small combs were well-planned artifacts requiring specialized preparation of raw materials, as well as skillful artisans to manufacture and produce these functional objects. Comb development was a cultural response to an endemic and increasingly annoyingly itchy health problem.

Key words: Pediculosis, *Pediculus humanus capitis*, lice, Pre-Columbian mummies, Atacama Desert, Chile.

*En este trabajo exploramos la hipótesis que los peines arqueológicos excavados en los sitios AZ71, PLM4, PLM6 y CAM8 en el norte de Chile fueron manufacturados específicamente para remover los piojos de la cabeza, huevos y ninfas. Para verificar esta propuesta se estudiaron microscópicamente un total de 41 peines almacenados en el Museo Arqueológico de la Universidad de Tarapacá, Arica, fechados entre el 240 y el 800 a.p., en busca de la presencia de fibras, piojos (*Pediculus humanus capitis*), huevos (liendres) y liendres eclosionadas, atrapados entre los dientes de los peines. El 56% (23/41) de los peines fueron positivos para la presencia de* P. humanus capitis *(piojos, huevos y liendres eclosionados). Ninguno de los peines presentó evidencia de fibras asociadas a la producción de tejidos y considerando los peines positivos para* P. humanus capitis*, el 17% (4/23) presentó restos de cabello humano entre sus dientes. Los peines fueron pequeños artefactos fabricados minuciosamente por los artesanos, guardando cuidado tanto en la selección de las materias primas utilizadas, como en la transformación de estas para llegar a conformar un peine funcional para la extracción de piojos y liendre/huevos. El desarrollo de los peines fue una respuesta cultural a una condición endémica y a un problema de salud que generaba un estrés constante en la población producto de la picazón.*

***Palabras claves:** pediculosis,* Pediculus humanus capitis*, piojos, momias precolombinas, desierto de Atacama, Chile.*

Infestation with the head louse, *Pediculus humanus capitis,* occurs worldwide and can be considered the most common parasitic infestation of children (Pilger et al. 2010). Pediculosis is associated with considerable morbidity. Whereas many patients remain asymptomatic, the condition can be extremely annoying for affected individuals. The most common symptom is severe pruritus (itching), caused by repeated blood-feeding by the parasites (Zuñiga and Caro 2010). Affected individuals are continuously scratching their heads, and have the potential for developing secondary bacterial infections of the scalp.

Pediculosis has accompanied humankind since ancient times in both the Old and New World, and affected communities probably applied various

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measures to reduce the pest burden and associated symptoms (Mumcuoglu 2008; Mumcuoglu and Zias 1988). In the Old World hair combs have been found in the Middle East (Levant) as early as the Natufian Period (13,950-11,950 BP) (Mumcuoglu and Zias 1989). Head lice combs are also known from ancient Egypt with one dated to about 1,450 to 1,550 BP (Mumcuoglu 2008; Palma 1991). Also 24 hair combs from Israel, Judean and Negev Deserts, dated between approximately 2,050-1,150 BP were reported in the literature (Mumcuoglu 2008; Mumcuoglu and Zias 1988). Most Old World combs were two-sided and made of wood; some were made from bone and ivory (Mumcuoglu 2008; Mumcuoglu and Zias 1988). In contrast, for the Americas, no in-depth studies of lice combs were found, only general information that these artifacts were associated with late agropastoral or fisher-gatherer populations (Dauelsberg 1972; Hidalgo and Focacci 1986). In contrast, the presence of *Pediculus humanus capitis* has been observed in the hair of South American mummies beginning as early as 10,000 BP (Araujo et al. 2000). Andean mummies show high prevalence of infestations of pediculosis (Arriaza et al. 2012, 2013; Reinhard and Buikstra 2003; Rivera et al. 2008). Pediculosis was endemic in Arica, northern Chile, affecting 4 out of 5 individuals (Arriaza 2013). Archaeological combs have been found as grave goods in ancient burials along coastal and inland sites in northern Chile. The purpose of these combs has not been resolved and is the subject of this investigation.

Here we explore the hypothesis that the fine combs found as grave goods in Arica archaeological sites were produced not only for combing the hair, but above all to mechanically remove head lice and their eggs. Comb artifacts emerged during the Formative period (ca. 1,450 to 2,450 BP) likely associated with the increasing complexity of hairstyles, ornamentation and social stratification. Cassman (1997) reported that most combs were found among grave goods of females. She suggested that females were likely responsible for creating complex hairstyles especially for men based on mummy hairstyles. Also she hypothesized that women were using combs in the weaving process, since weaving appeared to be a female occupation as well, based on grave good distributions. Thus, microscopic investigation of these ancient combs was performed to gather bio-cultural information on their original usage. If the combs were used primarily, or even occasionally for textile manufacture, they would have a preponderance of textile fiber evidence. On the other hand, we would expect to find eggs and lice, or their body parts, and human hair between the tines, if they were used primarily for grooming or delousing.

Materials and Methods

We analyzed 73 pre-Columbian combs housed at the Museo Arqueológico San Miguel de Azapa, Universidad de Tarapacá, Arica, Chile. The combs in this study came from the grave goods of five late Arica sites excavated during the 1960s and 1980s: two from Arican coastal sites (Playa Miller-4/PLM4 and Playa Miller-6/PLM6), one from the Camarones coast (Camarones-8/CAM8) and two agropastoral inland sites in the Azapa Valley (Azapa-71/AZ71 and Azapa 71A) (Dauelsberg 1972; Focacci 1974; Hidalgo and Focacci 1986; Muñoz 1989; Santoro 1980). Of the available combs we selected 41 that had intact tines, and excluded all that had been cleaned previously for museum display. The combs have a temporal range from the Middle Period (950 to 1,350 BP), the Late Intermediate (650 to 950 BP), and into the Late Period (418 to 650 BP, Table 1). Archaeologists using the cultural contexts of the collective assemblages associated with each comb made these specific temporal assignments (Dauelsberg 1972; Focacci 1974; Hidalgo and Focacci 1986; Muñoz 1989; Santoro 1980).

Procedures

The following variables were systematically quantified in the combs: (a) shape and size, (b) type of raw materials for manufacture, (c) number of tines, (d) presence and absence of any stages of *P. humanus capitis* embedded in the tines of the combs, (e) gap separation measured at the points of the tines, and (f) types of fibers or other detritus embedded between the tines.

All combs were analyzed under a 10x magnification lens. We systematically inspected an area of 2 by 2 cm^2 on each comb to count and collect all evidence including fibers, eggs and lice (Figure 1). To follow conventions, here we report the observations scored as per 1 cm^2 area. We took two readings in each artifact and averaged counts. Microsamples of the combs (tines and fibers) were collected for identification of raw materials at the

Table 1. Combs studied by period and nits/eggs/lice prevalence.
Peines analizados por periodo y prevalencia de liendres y piojos.

Period	Sites	Location	Comb total	Selected combs	Number of positive combs with nits/eggs only	Number of positive combs with lice only	Number of positive combs with nits/eggs and lice	Total number of positive combs	Prevalence (%)
Middle	AZ71, AZ71a	Valley	20	8	3	0	3	6	75
Late Intermediate	PLM4, CAM8	Coast	46	28	6	1	8	15	53.6
Late	PLM6	Coast	7	5	1	0	1	2	40
Total			73	41	10	1	12	23	56

Bioarchaeology Laboratory, Universidad de Tarapacá. Ectoparasites collected were studied using light and electronic scanning microscopy.

Five reed comb fragments were available for sampling and sent to Beta Analytic (Miami, USA) for AMS radiocarbon dating. Two of these samples were from an adjacent and inland Azapa Valley site (AZ6) and had representative fragmentary tines with sufficient sample sizes available for dating (Table 2).

Statistical analysis

Statistical analysis was done with Winstat software (version 2001.1 for Windows). The null hypothesis was rejected at $p < 0.05$, which was regarded as significant. We also did descriptive statistics on comb morphology, and correlation coefficient analysis for tine separation and egg density.

Results

The five conventional radiocarbon dated combs ranged in age from 240 to 800 BP. Two dates taken from the inland site AZ6 cluster with the Late Intermediate period and the three coastal samples were from the Late Period (Table 2). The two sigma calibration of the dates pushed the three dates from the coastal sites PLM4 and PLM6 to the contact period. There were a few Spanish artifacts such as glass beads or iron nails associated with these sites. However, the main archaeological contexts associated with these individuals had artifacts from the San Miguel and Gentilar cultural phases and Inka cultural influence (Hidalgo and Focacci 1986).

All combs were square shaped with a double row of tines (Figures 1 and 2). The 41 analyzed combs measured, on average, 62.4 mm (length) [SD = 16] by 62.7 mm (width) [SD = 15.2]. All combs, except one, were manufactured with tines tightly packed and held together in the middle by two horizontal wooden bars (one on each side) wrapped with fine cotton or naturally pigmented or dyed camelid threads (Figures 1 and 2). For these combs, 87.8% (36/41) were produced with monochrome threads and 12.9% (5/41) had decoration made from wrapping with camelid threads with two contrasting colors to form geometric patterns (Figures 1 and 2). The combs were made by tightly packing carefully sanded or smoothed wooden tines. Since tines spanned both sides of the comb, they were symmetrical, with

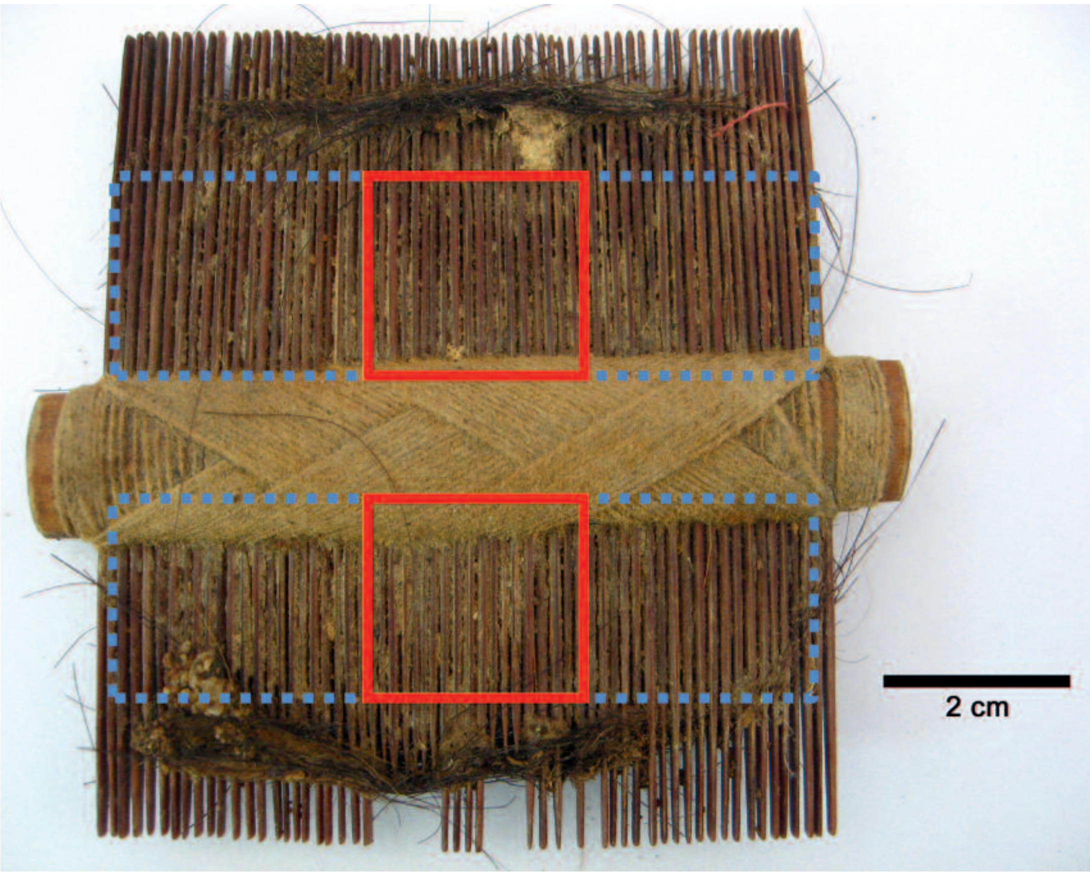

Figure 1. Plain archaeological comb PLM4T140, Nº 9606 with lice, nit/egg and hair *in situ*. The square boxes represent the analyzed 2 x 2 cm area. The dashed lines indicate where eggs/nits/lice accumulate. Maximum length: 71.3 mm by maximum width: 67.4 mm. Note the highly visible inclusions in this example.

Peine arqueológico simple o sin decoración, caso PLM4T140, Nº 9606, con evidencias de piojos, huevos (operculados y eclosionados) y cabello in situ. El segmento de 2 x 2 cm representa el área analizada y la línea punteada indica la acumulación de restos de piojos y liendres. Largo máximo: 71,3 mm y ancho máximo: 67,4 mm. Nótese la alta cantidad de restos orgánicos presentes en el peine.

the arbitrary left side having an average of 40.6 tines (SD = 13.7) and the right side having 42.5 tines (SD = 14).

The only fiber embedded in the combs was human hair; no fibers were associated with textile production, despite cotton and camelid fiber use in binding the combs in the first place. On those combs positive for *P. humanus capitis*, 17.4% (4/23) presented human hair embedded in the tines and 82.6% (19/23) did not have any type of fibers present. On those combs negative for *P. humanus capitis*, 16.7% (3/18) had evidence of human hair and 83.3% (15/18) did not present any type of fiber, human or textile-related (Table 3).

Scanning electron microscopy (SEM) analyses of eight comb threads that secured the tines in place showed the presence of cotton fibers (*Gossypium* spp.) in five cases, two cases used animal fibers only (scale patterns resemble camelid fibers) and one case had a mixture of both animal and cotton fibers (Figures 6 and 7). The SEM micromorphology of the tines (Comb PLM6 T11 3398.1) and the wooden bar or block that held the tines in place (Comb PLM6T10 3384) indicated the use of reed (*Phragmites australis*) as the raw material (Figures 8-9). Reed was readily available locally in the wetland areas of the river deltas and along the Lluta and San Jose rivers.

A total of 23/41 combs (56%) were positive for *Pediculus humanus capitis* (nits/eggs and/or lice). Of these, 10 (43.5%) had nits/eggs only, 12 (52.2%) nits/eggs and lice, and 1 (4.3%) comb had lice only.

Table 2. Summary of radiocarbon dates for combs.
Resumen de fechados radiocarbónicos de los peines.

Reference Sample	Type of material dated	Conventional radiocarbon age (BP)	Sigma	13C/12C Ratio ‰	Calibrated Intercept Date	1 Sigma calibrated (68% probability)	2 Sigma calibrated (95% probability)	Lab and number
AZ6T2/ 120.13.1	Reed (tine)	800	30	–24.7	Cal AD 1230 (Cal BP 720) and Cal AD 1230 (Cal BP 720) and Cal AD 1240 (Cal BP 710) and Cal AD 1250 (Cal BP 700) and Cal AD 1250 (Cal BP 700)	Cal AD 1220 to 1260 (Cal BP 730 to 690)	Cal AD 1190 to 1200 (Cal BP 760 to 750) and Cal AD 1210 to 1270 (Cal BP 740 to 680)	Beta Analytic 355399
AZ6T195/ 12843	Reed (tine)	560	30	–22.4	Cal AD 1400 (Cal BP 540)	Cal AD 1320 to 1340 (Cal BP 630 to 610) and Cal AD 1390 to 1410 (Cal BP 560 to 540)	Cal AD 1310 to 1360 (Cal BP 640 to 590) and Cal AD 1390 to 1430 (Cal BP 560 to 520)	Beta Analytic 355400
PLM4T96/ 8548	Wood (tine)	240	30	–25.2	Cal AD 1650 (Cal BP 300)	Cal AD 1650 to 1670 (Cal BP 300 to 280) and Cal AD 1780 to 1800 (Cal BP 170 to 160) and Cal AD 1950 to 1950 (Cal BP 0 to 0)	Cal AD 1640 to 1670 (Cal BP 310 to 280) and Cal AD 1780 to 1800 (Cal BP 170 to 150) and Cal AD 1940 to post 1950 (Cal BP 10 to post 1950)	Beta Analytic 365034
PLM6T11/ 3398	Reed (tine)	270	30	–25.4	Cal AD 1650 (Cal BP 300)	Cal AD 1640 to 1650 (Cal BP 310 to 300)	Cal AD 1520 to 1570 (Cal BP 430 to 380) and Cal AD 1590 to 1590 (Cal BP 360 to 360) and Cal AD 1630 to 1670 (Cal BP 320 to 280) and Cal AD 1780 to 1800 (Cal BP 170 to 160) and Cal AD 1950 to 1950 (Cal BP 0 to 0)	Beta Analytic 365035
PLM6T11/3398.1	Reed (tine)	260	30	–23.7	Cal AD 1650 (Cal BP 300)	Cal AD 1640 to 1660 (Cal BP 310 to 290)	Cal AD 1520 to 1560 (Cal BP 420 to 390) and Cal AD 1630 to 1670 (Cal BP 320 to 280) and Cal AD 1780 to 1800 (Cal BP 170 to 150) and Cal AD 1950 to 1950 (Cal BP 0 to 0)	Beta Analytic 365036

Figure 2. Decorated comb PLM4T171, Nº 10356 lashed together with bichrome threads (red and brown). Maximum length: 62.4 cm by maximum width: 59.1 cm.
Peine decorado, caso PLM4T171, Nº 10356, con sus dientes sujetados con hilos rojo y café. Largo máximo: 62,4 cm y ancho máximo: 59,1 cm.

The positive combs had an average separation or tine gap of 490 µm (SD = 217) at its widest point and the negative cases had similar values (470 µm, SD = 240). At the midline the tines presented minimal or no gap separation. The positive combs presented an average of 3.4 eggs/cm^2 (SD = 3.7) and an average of 0.7 lice/cm^2 (SD = 0.8) (adults and nymphs) trapped in the tines. The correlation between tine separation and egg density was low (r = 0.2). From positive combs we collected and microscopically analyzed a total of 47 lice (14 adults and 33 nymphs) and 283 nits/eggs (Figures 3-5). Of these nits/eggs, 91 (32.1%) were operculated or unhatched, 97 (34.3%) hatched, 2 (0.7%) were egg fragments with cementing substance and 93 (32.9%) were fragmented eggs or nits.

Table 1 shows that individuals in coastal sites from the Late Intermediate Period (PLM4 and CAM 8), more frequently had comb offerings than people from inland Middle Period sites (AZ71, AZ71A), 46 vs 20 respectively. But the Late Intermediate Period had 53.6% prevalence of combs infested with lice, while the Middle Period had 75%. Combs coming from coastal sites (n=16) tended to have similar egg densities compared to inland sites (n= 6), with 3.4 vs. 3.3 eggs/cm^2 and similar lice densities of 0.6 vs. 1.2 (n=10 and n=3) respectively. Table 3, provides a summary of all analyzed cases.

Table 3. Summary of cases analyzed.
Resumen de casos analizados.

Site	Tomb	Cultural period	Pediculosis	Lice counts reduced to 1cm^2 area*	Nit/egg counts reduced to 1cm^2 area (*)	N° tines right side	N° tines left side	Gap separation at the points of the tines (mm)	Maximum comb length (mm)	Maximum comb width (mm)	Maximum comb central thickness (mm)	Type of fiber found within the tines
AZ71a	T22_4627.2	Middle	Negative	0	0	50	47	0.61	71.0	60.7	10.6	None
AZ71a	T29_4661.1	Middle	Negative	0	0	36	36	0.21	43.5	42.7	8.2	None
AZ71a	T22_4627	Middle	Positive	1	2.5	61	55	0.43	80.5	69.2	10.2	None
AZ71a	T22_4627.1	Middle	Positive	2.4	8	58	49	0.41	77.5	69.1	12.2	None
AZ71a	T66_4808	Middle	Positive	0	7.9	30	20	0.93	44.8	40.4	6.8	None
AZ71a	T95_4960	Middle	Positive	0	0.4	34	30	0.1	86.2	82.6	16.1	Human hair
AZ71	T118_5025	Middle	Positive	0	0.8	24	27	0.65	65.7	63.4	13.7	None
AZ71	T151_5154	Middle	Positive	0.1	0.3	25	25	0.78	66.2	59.9	13.2	None
PLM4	T10_3384.1	Late Intermediate	Negative	0	0	49	49	0.55	79.4	89.3	10.8	None
PLM4	T18_6756	Late Intermediate	Negative	0	0	30	29	0.77	28.0	34.3	6.8	None
PLM4	T25_6935.1	Late Intermediate	Negative	0	0	34	27	0.57	59.8	75.4	10.2	Human hair
PLM4	T30_7075	Late Intermediate	Negative	0	0	29	29	0.98	83.7	92.1	15.6	None
PLM4	T34_7158	Late Intermediate	Negative	0	0	27	27	0.13	36.3	39.5	7.1	None
PLM4	T59_7724	Late Intermediate	Negative	0	0	54	54	0.3	83.4	77.1	12.1	None
PLM4	T119_9139	Late Intermediate	Negative	0	0	60	60	0.28	81.8	77.5	11.3	Human hair
PLM4	T119_9139.2	Late Intermediate	Negative	0	0	58	58	0.2	63.4	61.1	8.0	None
PLM4	T120_9164	Late Intermediate	Negative	0	0	69	63	0.56	78.6	76.3	12.4	None
PLM4	T138_9552	Late Intermediate	Negative	0	0	44	44	0.19	59.3	51.9	9.4	None
PLM4	T140_9607	Late Intermediate	Negative	0	0	41	41	0.39	69.4	80.1	12.9	None
PLM4	T171_10356	Late Intermediate	Negative	0	0	54	54	0.23	62.4	59.1	11.6	None
PLM4	T18_6756.2(c)	Late Intermediate	Positive	0	10	54	55	0.22	67.0	54.1	8.6	None
PLM4	T23_6878	Late Intermediate	Positive	0	0.3	21	21	0.42	45.8	49.8	8.6	None
PLM4	T23_6878.1	Late Intermediate	Positive	0.1	0.1	60	59	0.43	69.2	60.7	9.2	None
PLM4	T50_7496	Late Intermediate	Positive	0	0.1	31	31	0.45	62.2	66.0	12.1	None
PLM4	T70_7982	Late Intermediate	Positive	0.4	0.3	31	32	0.88	69.5	62.3	9.6	Human hair
PLM4	T94_8511	Late Intermediate	Positive	0.4	8.9	57	57	0.32	65.4	64.3	8.8	None
PLM4	T94_8511.1	Late Intermediate	Positive	0.1	1.1	52	52	0.31	64.5	57.2	9.9	None
PLM4	T96 _8548 (**)	Late Intermediate	Positive	0.1	0	61	24	0.45	71.4	72.0	6.5	None
PLM4	T117_9097	Late Intermediate	Positive	0	0.3	52	52	0.57	64.6	79.5	12.3	None
PLM4	T135_9481	Late Intermediate	Positive	0	1.8	39	39	0.44	56.3	62.6	9.7	None
PLM4	T136_9514	Late Intermediate	Positive	0	7.3	43	43	0.38	53.8	55.8	11.2	None
PLM4	T140_9606	Late Intermediate	Positive	0.4	0.3	61	61	0.36	71.3	67.7	11.3	Human hair
CAM8	T19_20261	Late Intermediate	Negative	0	0	28	28	0.83	84.0	82.5	17.8	Human hair
CAM8	T12_20120	Late Intermediate	Positive	0.1	3.3	34	34	0.41	39.3	42.2	8.9	None
CAM8	T12_20111	Late Intermediate	Positive	2.5	9.4	32	32	0.37	42.6	44.3	8.8	None
CAM8	T14_20185	Late Intermediate	Positive	0.9	7.8	24	25	0.35	42.3	45.3	7.8	Human hair
PLM6	T10_3384	Late	Negative	0	0	50	50	0.64	67.5	77.1	12.4	None
PLM6	T11_3395	Late	Negative	0	0	24	24	0.45	32.4	40.1	9.8	None
PLM6	T11_3398	Late	Negative	0	0	36	36	0.54	45.2	62.2	12.1	None
PLM6	T7_3334	Late	Positive	0	2.1	24	24	0.85	38.5	42.0	10.2	None
PLM6	T11_3398.1	Late	Positive	0.6	2.1	61	61	0.75	83.2	82.9	24.0	None

* All values should be multiplied by 4 to obtain “in situ” mean nit/egg and lice density scored values.
** Wooden comb, compact tines had 0.45 mm gap and the widely spread 1.7 cm gap.

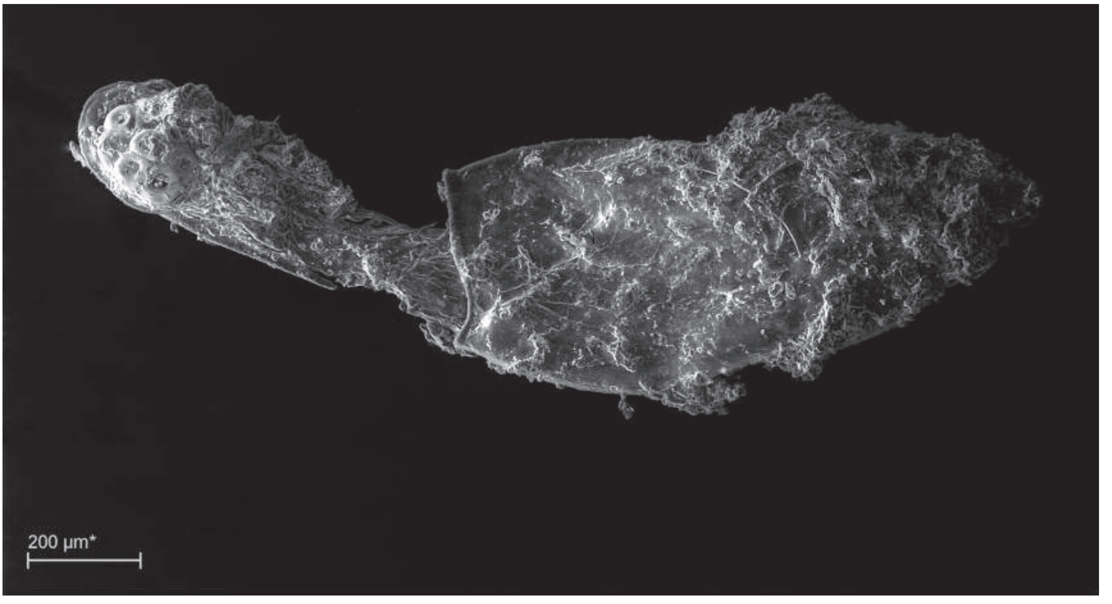

Figure 3. Flattened egg/nit with a louse embryo bursting out, taken from comb PLM4T94, Nº 8511. SEM imagen, 150X.
Huevo aplanado con un embrión de piojo emergiendo. Muestra recolectada del peine PLM4T94, Nº 8511. Imagen de SEM, magnificación 150X.

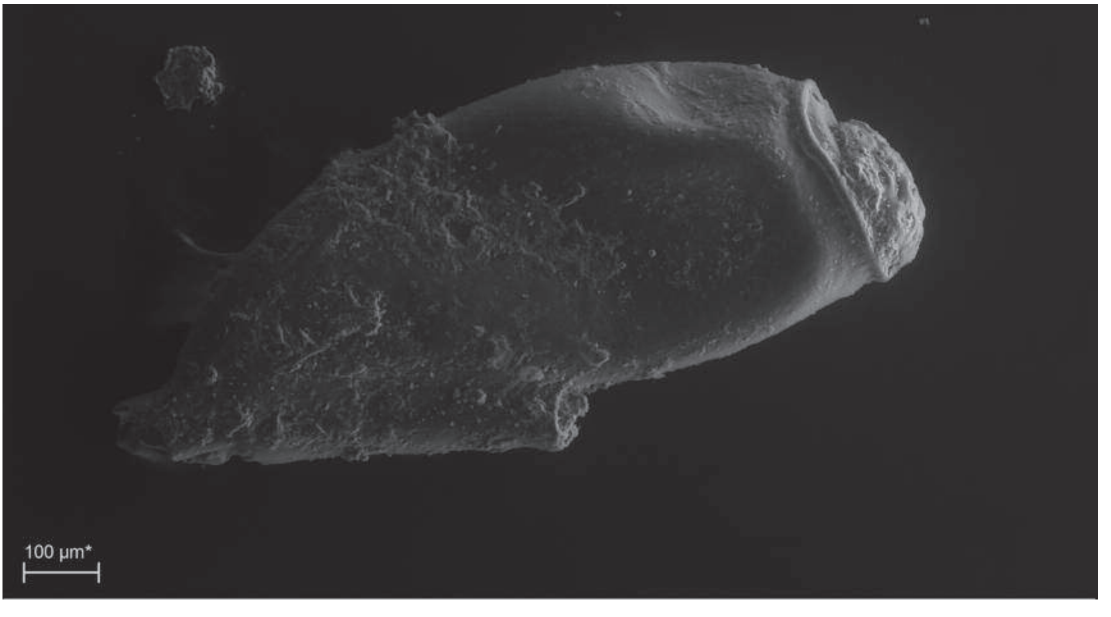

Figure 4. Unattached louse egg taken from comb PLM4T63, Nº 7810. SEM imagen, 200X.
Huevo operculado (sin eclosionar). Muestra recolectada del peine PLM4T63, Nº 7810. Imagen de SEM, magnificación 200X.

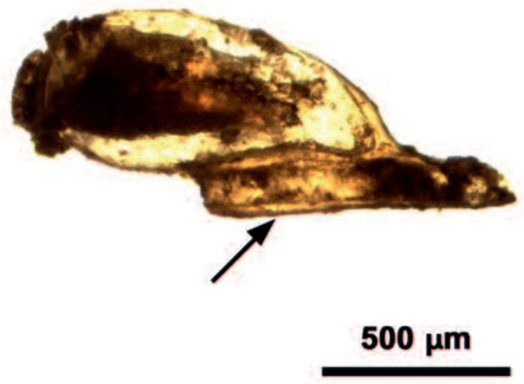

Figure 5. Unhatched louse egg taken from comb PLM6T7, Nº 3334. Note empty cement or imprint of the hair shaft (arrow). Light microscopy, 4X.
Huevo operculado donde además se observa el molde (flecha) de un cabello en la sustancia cementante. Muestra recolectada del peine PLM6T7, Nº 3334. Imagen de microscopía óptica, magnificación 4X.

Discussion

The cultural evidence associated with the five sites presented, revealed complex sociopolitical organization, significant population density, status competition, mobility and large spheres of interaction (Goldstein1995-1996; Hidalgo and Focacci 1986; Muñoz 1989; Muñoz 2005; Santoro 1980). These social variables increased the probability for ectoparasite infestations, and the need for lice control.

An alternative interpretation to the head lice removal hypothesis is that the combs were simply manufactured to groom the hair. In this case the presence of parasites embedded in the tines simply would reflect health conditions when the hair was combed. However, from a practical point of view, anyone who has tried to use a lice comb on unruly hair would know that this is impractical – hair that is tangled would tear necessitating the use of fingers, or

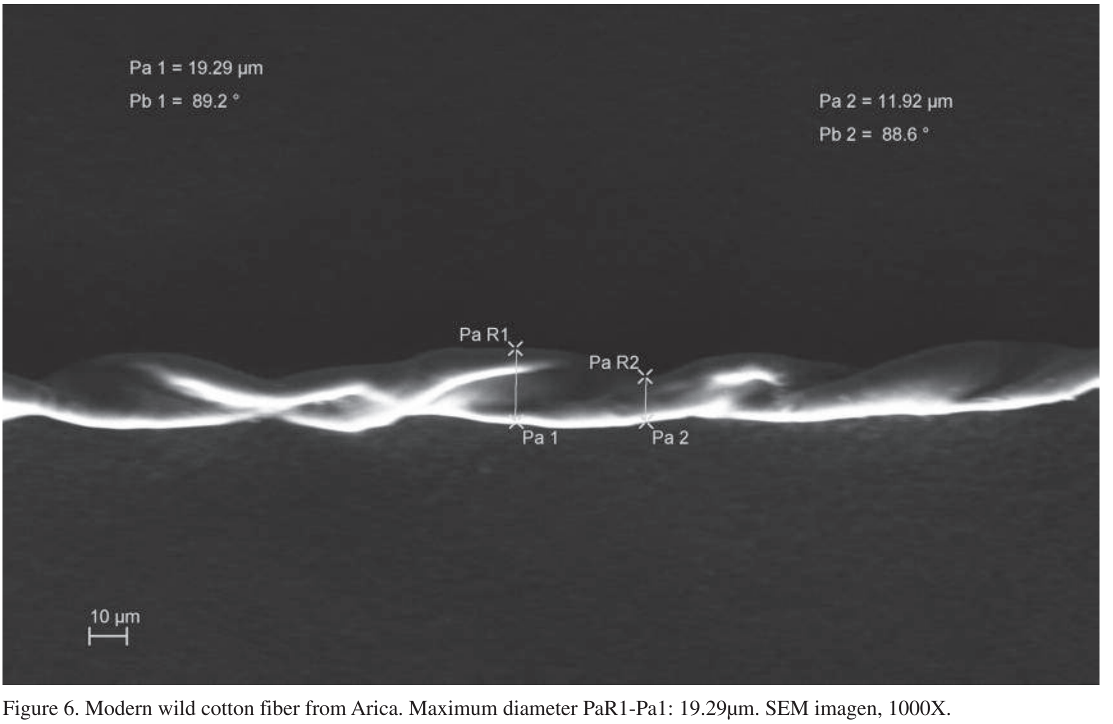

Figure 6. Modern wild cotton fiber from Arica. Maximum diameter PaR1-Pa1: 19.29µm. SEM imagen, 1000X.
Muestra de algodón actual de Arica. Diámetro máximo PaR1-Pa1:19,29 µm. Imagen de SEM, magnificación 1000X.

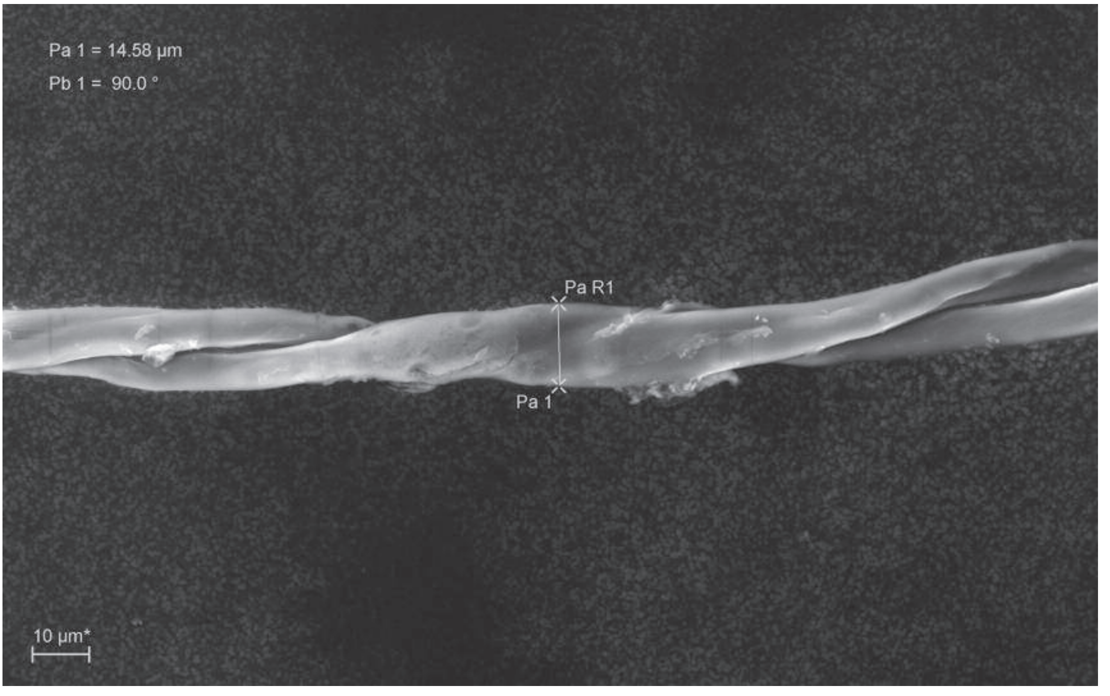

Figure 7. Close up of an archeological cotton fiber taken from comb PLM4T50, Nº 7496. Maximum diameter PaR1-Pa1: 14.58µm. SEM image, 1500X.
Detalle de una muestra de algodón arqueológico. Muestra recolectada del peine PLM4T50, Nº 7496. Diámetro máximo PaR1-Pa1: 14,58 µm. Imagen de SEM, magnificación 1500X.

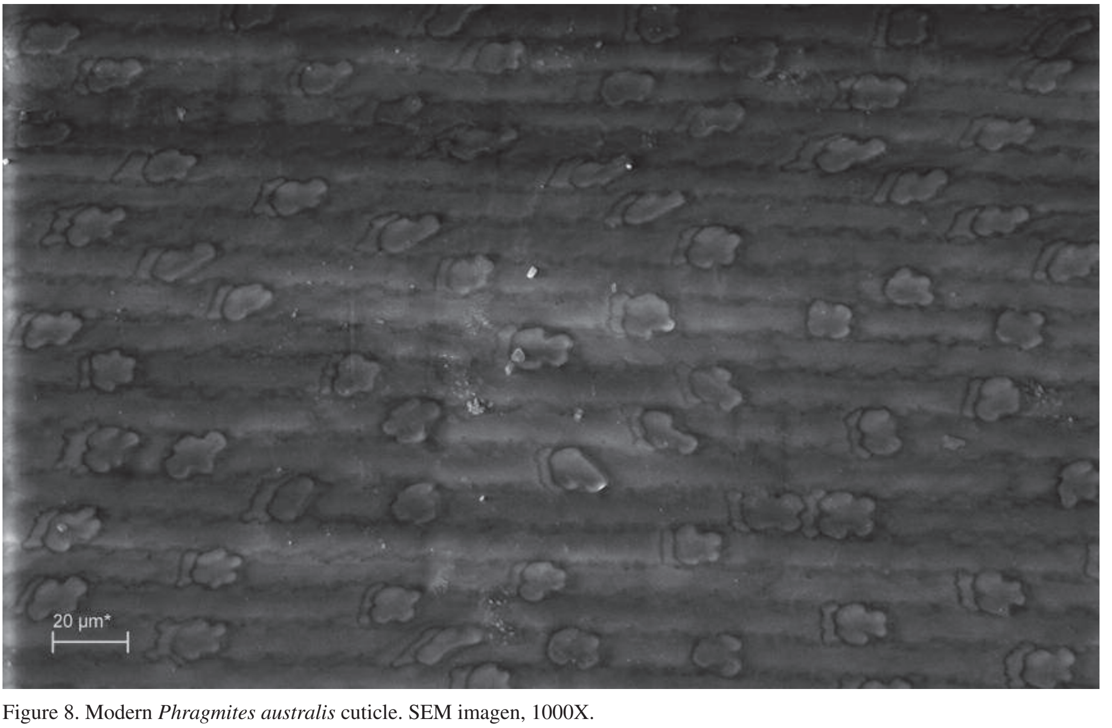

Figure 8. Modern *Phragmites australis* cuticle. SEM imagen, 1000X.
Muestra actual de cutícula de Phragmites australis. Imagen de SEM, magnificación 1000X.

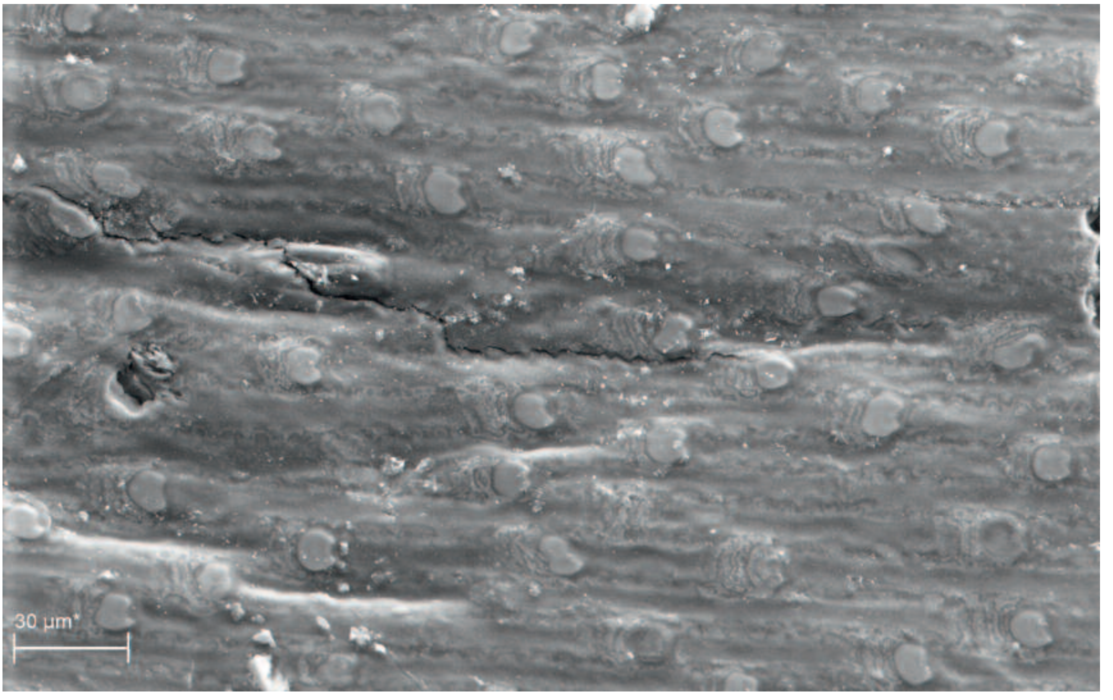

Figure 9. Cuticle from horizontal bar of comb case PLM6T10 Nº 3384. SEM imagen, 1000X.
Cutícula de la barra horizontal del peine. Muestra recolectada del peine PLM6T10 Nº 3384. Imagen de SEM, magnificación 1000X.

more efficiently, a widely spaced comb first, and then secondarily a densely packed lice comb. In Arica during these periods, long hair appears to be the norm, thus the compact combs would not have been the ideal tool for grooming hair. In the archaeological record for Arica, a few combs have been found that contained both narrow and widely spaced options (Figure 10, comb from PLM4 dated 240 ±30 BP). The presence of the two options, narrow and wider spaced combs, plus the predominance of long hairstyles, made the specialized use of compact combs for lice removal more plausible. There were extra labor costs involved in making a dense comb, especially for those with the decorative wrapping, when a widely spaced comb would have been more effective for grooming hair in general. Thus the comb data indicated these prehistoric Arica populations created functional objects for delousing and grooming. Considering the small size of the combs, narrow separation of the tines, absence of embedded camelid hair or cotton fibers, the labor intensive production techniques, the reduced efficiency of combing tangled hair with a dense comb, and especially the presence of lice eggs, nymphs and adult lice trapped in the tines, all add up to indicate these combs were specifically manufactured to remove lice.

An average modern louse egg is ovoid and about 888 µm in length (SD = 27) and 460 µm wide (SD = 22) (Kadosaka and Kaneko 1985). In our ongoing studies of archaeological head lice eggs (n=17), these measured 880 µm in length (SD = 55) by 370 µm wide (SD = 27). Ancient eggs were thus slightly smaller in width compared to modern samples, which may be attributed to the highly dehydrated state of the ancient remains. In addition, an adult head louse measured about 2-3 mm in length. Thus, for effective head lice removal, a delousing instrument must have had small enough gaps to trap not only adults but also nymphs and eggs. According to Larsen (2010) modern lice combs have tines with a distance of no more than 200-300 µm apart to efficiently remove all stages of lice. A gap of 61 µm will remove 100% of all life stages of a louse. The positive Arica prehistoric combs in this study had an average separation or tine gap of 490 µm (minimum =100µm), less efficient than modern combs, but fine enough to remove eggs, and therefore later life stages too (Table 3).

Figure 10. Plain archaeological comb made from one piece of wood. Note the tines do not span the entire comb. One side with compact tines (0.45 mm gap) and the other widely spread (1.7 mm gap). Maximum length: 71.4 mm by maximum width: 72 mm. Case PLM4T96, Nº 8548.
Peine arqueológico de una sola pieza de madera y sin decoración. Los dientes no presentan continuidad y en un lado son muy compactos (0,45 mm de separación) y en el otro presentan mayor separación (1,7 mm). Largo máximo: 72 mm y ancho máximo: 74 mm. Caso PLM4T96, Nº 8548.

The correlation between teeth gap and egg density was low (r = 0.2), perhaps the consequences of intentional cleaning of the combs in prehistory. Considering the average 3.4 nit or egg density in the prehistoric combs, along with the average dimensions of the complete combs (6 x 6 cm) and the fact that head lice and eggs were trapped at the midline of the combs, then each comb had the potential to catch about 80 eggs and 17 lice on a 24 cm^2 area, if both sides of the comb were used. The observed and extrapolated values, as well as the different stages of lice trapped in the combs (eggs, nymphs and adults) showed that these ancient artifacts were excellent tools to reduce population or carrying capacity of lice on individuals who regularly used the combs.

In Arica and surrounding areas, combs for delousing were manufactured for centuries. Though combs were effective tools for removing head lice, prevalence of lice was still high during the Middle and late Periods (Arriaza et al. 2012; Reinhard and Buikstra 2003). Several factors, such as preference for long hair, complex hairstyles likely worn for days, and increasing population densities over time, increased the likelihood of head lice infestations. Moreover, the population of *Pediculus humanus capitis* was likely only temporarily altered by grooming, considering the high reproductive rate of head lice.

Mechanical removal of head lice, even of the larger adults is a laborious task, and a time consuming effort undertaken usually by close kin. Efficient nit picking measures require a collaborative effort; someone else needs to do the grooming either using their nails to get adults, and/or an artifact such as a comb to remove eggs which are cemented at the base of a strand of hair and all other stages (Burkhart and Burkhart 2005).

It is not known if ancient communities used plant-based deterrents or shampoos to remove ectoparasites, but a heavily infected individual could have taken the drastic solution to cut off their hair completely, as is done still today in many societies. However, in the Andes, ancient people took much care and pride in their long hair, and during Inka times it was considered a punishment to have one's haircut (Cieza de León 1553; de La Vega 1609). In Arica, mummies with short hair from these sites are infrequent; about 11% (18/154), which includes children (Arriaza et al. 1986). On the contrary, ancient Arican populations had long, healthy, thick hair. After 3,450 BP women styled their hair in simple single or double braids, but men could have very elaborate hairstyles (Arriaza et al. 1986). Thus, in northern Chile, extreme haircuts would have been for the most part out of the question and an exception rather than a common remedy to treat head lice.

Instead, ancient Arica people learned how to cope with lice infestations and likely spent many hours grooming and removing head lice. Combs developed starting in the Formative period, were one form of partial control. Head lice presence was likely an annoying pandemic in the ancient Americas. In fact, our ongoing studies have shown that 84.5% (186/220) of Arica mummies (coastal and inland) show presence of *Pediculus humanus capitis* eggs (Arriaza 2013). Prevalence was so high that during the Late Horizon Period, the ethnohistorical accounts told us that the Inkas requested people too poor to pay taxes, to pay in live lice so that they would be used to giving of what they had produced (Cieza de León 1553; de La Vega 1609). Also this may have been an attempt to discourage lice accumulation among the impoverished.

It appeared being near the ocean made little difference in the carrying capacity of combs. However a different conclusion is drawn, when the comb data are compared to nit or egg densities found on the actual heads of the mummies. A complementary ongoing study of the hair of individuals from corresponding sites and time periods shows that Arica coastal populations had an average of 1.5 eggs/cm^2, while inland agropastoral individuals had 3.1 eggs/cm^2 ($p \leq 0.001$) (Arriaza 2013). Given the natural coastal setting and temperate water, coastal people were probably bathing, cleaning, grooming and delousing more often than inland settlers could. Conceivably this is the reason why coastal individuals tended to have more combs in their grave goods and why coastal mummies have significantly fewer eggs. The combs, however, were equally efficient at lice removal whether at the coast or inland, and therefore do not have significantly different outcomes, unlike the studies of lice embedded in the hair of mummies themselves.

Conclusions

Our study showed for the first time that ancient combs found in five prehistoric Arica sites were solid testimony of prehistoric health practices and efforts to control endemic lice infestations. Head lice combs were probably the oldest antiparasitic therapy, and are still used today, with very few adaptions in thousands of years.

Comb innovations and development were a cultural response to an endemic and annoying problem. Ancient Arica populations learned that comb tines needed to be sufficiently packed together to remove lice and their eggs efficiently. These populations, particularly during the Late Intermediate and Late Period, actively sought a practical solution to minimize pediculosis, creating combs from raw materials that were locally available. Combs contributed to control, but despite their relative effectiveness, pediculosis was a persistent problem for these ancient populations. Our regional findings increase the spectrum of prophylactic health measures available in antiquity. It provides detailed information on ancient lice combs and degree of infestations. We show for the first time that Arica prehistoric combs were manufactured to control head lice, independent of secondary usages. They were not just artifacts that accompanied the dead in the afterlife, but practical and fully functional health improvement tools. Prehistoric Old and New World populations were affected by pediculosis, and both created similar solutions, easy to grip, strong double-sided lice combs.

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