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by Toetik Koesbardiati

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Ritual tooth ablation and the Austronesian expansion: Evidence from eastern Indonesia and the Pacific Islands

Rebecca Lorraine Kinaston[a], Toetik Koesbardiati[b], Rusyad Adi Suriyanto[c], Hallie Ruth Buckley[a], Siân Ellen Halcrow[a], Aimee Foster[d], Truman Simanjuntak[e], Stuart Bedford[f], Delta Bayu Murti[b], Rizky Sugianto Putri[b], and Jean-Christophe Galipaud[g]

[a]Department of Anatomy, School of Biomedical Sciences, University of Otago, PO Box 913, Dunedin, New Zealand; [b]Department of Anthropology, Faculty of Social and Political Science, University of Airlangga, Surabaya, Java, Indonesia; [c]Laboratory of Bioanthropology and Paleoanthropology, Faculty of Medicine, Public Health and Nursing, Gadjah Mada University, Yogyakarta, Indonesia; [d]Department of Archaeology, Anthropology and Forensic Science, Bournemouth University, Fern Barrow, Poole, Dorset. BH12 5BB, United Kingdom; [e]National Research and Development Centre for Archaeology (Pusat Penelitian dan Pengembangan Arkeologi Nasional), Jalan Raya Condet Pejaten 4, Jakarta 12510, Indonesia; [f]Archaeology and Natural History, School of Culture, History and Language, College of Asia and the Pacific, Australian National University, ACT 2601, Australia; [g]UMR Paloc, Research Institute for Development/National Museum of Natural History, 57 rue Cuvier, CP 51, 75231 Paris CEDEX 05, France

ABSTRACT

Ritual tooth ablation, the intentional removal of teeth, is a highly visible form of body modification that can signal group identity and mark certain life events, such as marriage. The widespread occurrence of the practice in Asia appears to have begun in the Neolithic period and in some areas, such as Taiwan, continued until the ethnographic present. We aim to use a biocultural approach to investigate the significance of tooth ablation in Indonesia and Vanuatu during the maritime expansion of Austronesian-speaking groups ca. 3500–2000 years ago. Here we assess the presence and patterns of tooth ablation in four prehistoric skeletal assemblages from eastern Indonesia (Pain Haka, Melolo, Lewoleba and Liang Bua) and one from Vanuatu (Uripiv). Despite the relatively small sample sizes, it was found that individuals from all the sites displayed tooth ablation. The Indonesian populations had ablation patterns that involved the maxillary lateral incisors and canines and the individuals from Uripiv had the central maxillary incisors removed. We suggest that the distribution of tooth ablation in eastern Indonesia provides strong evidence that this practice was an important ritual process associated with the early expansion of Austronesian-speaking populations in the region. The identification of tooth ablation at the site of Uripiv is the earliest example of the practice in the Pacific Islands and was either a Southeast Asian tradition brought by Austronesian settlers, was introduced later from Near Oceania, or was an indigenous development in Vanuatu. A similar pattern of tooth ablation (the removal of central maxillary incisors) has been documented in ethnographic reports of northern Vanuatu tribes. We argue that the practice could possibly be a ritual passed through the generations since the early settlement of Vanuatu.

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CONTACT Kinaston, Rebecca Lorraine rebecca.kinaston@otago.ac.nz Department of Anatomy, School of Biomedical Sciences, University of Otago, PO Box 913, Dunedin, New Zealand.

Introduction

The maritime expansion of Austronesian (AN)-speaking populations throughout Island Southeast Asia (ISEA) and eventually Oceania was the most extensive prehistoric maritime migration in the world. Today, people speaking Austronesian languages live across a vast geographical area from Madagascar in the west, through Mainland Southeast Asia (MSEA) and ISEA and across the Pacific Ocean, from Papua New Guinea to the farthest reaches of Polynesia (Ross 2008). It is believed that Austronesian languages originated in Taiwan (Blust 1995), but there remain uncertainties surrounding multiple facets of the Neolithic migrations of AN-speaking populations, including their belief systems and rituals, and interaction with non-AN-speaking (NAN) populations already settled in some regions, such as Island Southeast Asia and Near Oceania (Bulbeck 2008; Donohue and Denham 2010; Kirch 2010; Spriggs 2011; Terrell 1988).

In the Pacific Islands, prehistoric Austronesians settled thousands of islands over vast areas of open-ocean. Alongside broad-spectrum foraging, a "transported landscape" of plants, animals, and technological knowledge is thought to have been essential for the success of their settlements, allowing for the establishment of gardens, animal husbandry, and the manufacture of material items (e.g., pottery, stone tools, bark cloth and shell jewelry) (Kirch 2010; Kirch 2017). The components of this transported landscape would have varied depending on the timing and location of settlement and this is especially true in regard to Austronesian Lapita populations in the Pacific compared to Austronesian populations who settled Micronesia (Carson 2013; Spriggs 2011). The variable nature of the Austronesian "package" can be seen from the numerus influences from SEA such as pigs (*Sus scrofa*), betel nut (*Areca catechu*), taro (*Colocasia esculenta*) chickens (*Gallus gallus*), rats (*Rattus exulans*), and spindle whorls (Cameron 2002; Larson et al. 2010; Lebot et al. 2004; Spriggs 1996; Storey et al. 2010); and from the western Pacific with banana (*Musa* spp.), sugarcane (*Saccharum officinarum*), and canarium nut (*Canarium* spp.) (Donohue and Denham 2010; Kennedy 2008; Lebot 1999; Yen 1996). These items undoubtedly had more than just utilitarian significance and were part of a larger Neolithic package of ideas, identity, culture, and social structures that spread with Austronesian speakers (Spriggs 2011). Many of these foods form an important aspect of life in areas of modern-day ISEA and the Pacific, in both daily subsistence and special events, including feasts.

The analysis of human remains from Neolithic Austronesian contexts provides direct evidence for physical modifications that may have resulted from cultural or ritual behavior. Around the world humans have, and still do, modify their bodies for cultural and spiritual purposes using tattoo, piercing, scarification, skull deformation and tooth modification (removal, filing, incising and blackening) (e.g., Burnett and Irish 2017; Clark and Langley 2019; Clark 2013; Pitts 2003; Te Awekotuku 2003).

The purposeful removal of teeth (tooth ablation) is a cultural process that has been used as an identifier of community inclusion and attaining certain life-stage events, such as marriage and coming of age, while also increasing a person's aesthetic appeal (Burnett and Irish 2017; Deacon 1934; Milner and Larsen 1991). Investigating the patterns of tooth modification in past populations may illuminate aspects of ritual behavior and identity not otherwise detectable in the archaeological record. The current study applies a biocultural approach to investigate the tradition of tooth ablation at Neolithic

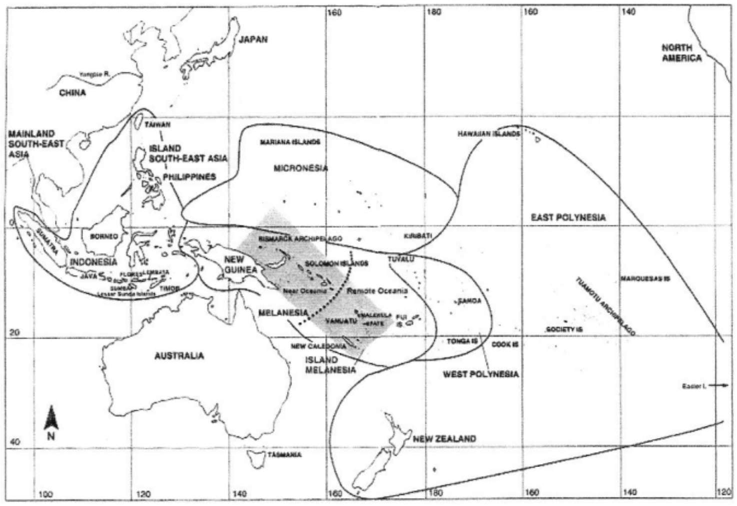

Figure 1. Map of Island Southeast Asia and the Pacific Islands with islands mentioned in the text. The ---- line denotes the boundary between Near and Remote Oceania (map adapted from Spriggs 1997).

sites in ISEA and the Pacific. Biocultural interpretations of archaeological human remains from the Pacific and Southeast Asia have already provided information about social organization (Kinaston et al. 2014a; Kinaston et al. 2014b; Oxenham 2006), vulnerability to early mortality or injury (Domett and Tayles 2006; Halcrow, Tayles, and Livingstone 2008), economy and subsistence (Kinaston et al. 2016a; King and Norr 2006), nutritional adequacy (Buckley et al. 2014), and ritual behavior and identity (Oxenham et al. 2016; Scott and Buckley 2014; Tayles 1996).

We aim to use direct analyses of human remains, specifically the occurrence of tooth ablation in four skeletal assemblages from eastern Indonesia (Pain Haka, Melolo, Lewoleba, and Liang Bua) and one from Vanuatu (Uripiv) that date to the Neolithic period (~3500-2000 BP) (Figure 1), to assess how cultural, behavioral, and social systems shaped biological responses to the environment (Clark et al. 2017; Larsen 2015; Schell 1997). We argue that tooth ablation was an important component of the Neolithic cultural package associated with the migration of Austronesian peoples throughout some regions of Southeast Asia, which may have been carried into the Pacific during the early human settlement of Remote Oceania ca. 3000–2500 BP.

Austronesian settlement of ISEA and the Pacific

The original "Out of Taiwan" model linked the spread of Austronesian languages with rice agriculture and a large north to south migration of people into ISEA, starting around 5000 BP (Bellwood 1997; Pawley 2004). This model has been revised by

Bellwood and colleagues (e.g., Bellwood et al. 2011; Bellwood and Dizon 2008; Piper et al. 2009) and challenged by genetic (Hudjashov et al. 2017; Ko et al. 2014; Lipson et al. 2014; McColl et al. 2018; Soares et al. 2008; Soares et al. 2016), archaeological (or lack thereof, cf. Spriggs 2011), bioarcheological (Matsumura 2010), and linguistic evidence (Denham and Donohue 2009; Denham and Donohue 2012; Donohue and Denham 2010) that emphasizes the complexities of human interaction in the region before, during and after the Neolithic.

In the Pacific, evidence for a more direct expansion of Austronesian populations is clearer, especially Remote Oceania, and marked by the appearance of intricately decorated pottery, termed Lapita, in the Bismarck Archipelago dating to 3300 BP (Summerhayes et al. 2010b). Lapita populations rapidly sailed east and south from the Bismarck Archipelago, settling coastal areas in the Solomon Islands and reaching the previously uninhabited islands of Vanuatu, New Caledonia, Fiji, Tonga, and Samoa (Kirch 2010; Kirch 2017). Regional transformations (and possible migrations from Micronesia, see Addison and Matisoo-Smith 2010) subsequently occurred, and around 1500–1000 BP people moved from the "Polynesian Homeland" of Fiji, Tonga, and Samoa into Eastern Polynesia, culminating in the settlement of Hawaii and New Zealand approximately 700–800 BP (Kirch 2017).

In Micronesia, the earliest evidence for Austronesian settlement has been dated at Marianas sites by some researchers as 3500 BP (Hung et al. 2011; Winter et al. 2012), but recent Bayesian calibration models of radiocarbon dates suggest an initial settlement date of 3230–3085 BP (Rieth and Athens 2019). Later dates for settlement of the Palauan archipelago (ca. 3100–2900 BP) have also been proposed ca. from radiocarbon dating of archaeological sites (Clark, Anderson, and Wright 2006; Fitzpatrick 2003; Stone, Fitzpatrick, and Napolitano 2017). Differences in material culture, subsistence (e.g., rice in Marianas), aDNA (Lum and Cann 2000; Lum, Jorde, and Schiefenhovel 2002), and cranial morphology (Pietrusewsky 1990) indicate a separate migration event to that of the Lapita voyagers, although there is debate surrounding origins and settlement timing (e.g., Carson 2011; Carson and Kurashina 2012; Fitzpatrick and Callaghan 2013; Hung et al. 2011; Montenegro, Callaghan, and Fitzpatrick 2016).

Evidence for prehistoric Austronesian cultural and ritual practices

There is limited material evidence available to assist with understanding Austronesian belief systems or ritual practices during the *initial* expansion period apart from evidence observed from burial ritual (discussed below). However, megalithic structures, rock carvings, increased housing density, evidence for intensive agriculture, and burial traditions (e.g., mounds and tombs) indicate increasing social stratification and associated ritual in *later* prehistory, especially in Polynesia and Micronesia (Kirch 1984; Wallin and Martinsson-Wallin 2011). Across the Pacific Islands, historical and ethnographic accounts show that many ritual items used in ceremonies for cultural and spiritual purposes (i.e., coming of age, circumcision, marriage, status promotions, healing, witchcraft, and funerals) were made from organic materials such as wood, plant fibers, and leaves (e.g., bark cloth, mats, masks and drums), all of which are rarely preserved in the archaeological record (Deacon 1934; Kirch 2017; Layard 1942; Lutkehaus and Roscoe 1995; Muller and Guiart 1972; Oliver 1989; Speiser [1923] 1990).

Today, tattooing is one of the most well-known examples of body modification in some Pacific and ISEA societies and many tattoo designs are a highly ornate and visible form of identity (e.g., Barton 1918; Parkinson [1908] 1999; Speiser [1923] 1990). Research of use wear and residue analysis of retouched obsidian flakes from Lapita and earlier mid-Holocene sites in the Pacific Islands has identified that these objects were used for tattooing from prehistoric times (Clark and Langley 2019; Kononenko 2012; Kononenko, Torrence, and Sheppard 2016; Torrence et al. 2018). The dentate-stamped method of design on Lapita pottery has also been associated with tattooing (Green 1979; Kirch 1997), although this has been debated (Ambrose 2012; Bedford and Sand 2007). However, little direct evidence for tattoos have been discovered in prehistoric ISEA or the Pacific populations because skin is almost never preserved in the burial environment, particularly in tropical climates. One notable example of historic tattoo preservation in the Pacific Islands are the Mokomokai, tattooed preserved heads of Māori, from New Zealand (Aotearoa).

Animals of high intrinsic value such as pigs are commonly gifted and feasted upon during ceremonies in Oceania (Hide 2003; Speiser [1923] 1990), but unless specific culturally valuable parts are found archaeologically, such as pig tusks, it is difficult to differentiate these remains from everyday animal use for food. Of the artifacts that may be preserved in the archaeological record, Neolithic Austronesian cultures used stone, shell, clay, bone, and teeth to manufacture material items. Thus, material culture in these regions displays an abundance of utilitarian items, many of which would be indiscernible as ritual artifacts unless discovered within a special context, such as a cemetery (see discussion by Marshall in Sand et al. 2013). One such example are *Conus* multi-segment broad rings. Isolated segments, represented by a worked square piece of *Conus* shell with drilled perforations at each corner, have been recovered from multiple Lapita sites. However, it was not until multiple segments were found adorning the ankles of a burial at the Teouma cemetery on Efate, Vanuatu, that researchers realized the segments were tied together to be used as jewelry (Langley et al. 2019).

Burial practices are a reflection of cultural and spiritual processes that surround death, and people's ideas of the afterlife. Burial practices may also reflect a person's social status during life (Härke 2000; Kinaston, Buckley, and Gray 2013). Grave goods, in the form of pottery (decorated and plain), shell, and stone artifacts are associated with Neolithic burial grounds throughout Taiwan (Bellwood 2007; Hung et al. 2013; Hung and Ho 2006), the Philippines (Bellwood and Dizon 2013; Fox 1970), Indonesia (Bintarti 2000; Chazine 2005; Galipaud et al. 2016; Lloyd-Smith 2013; Simanjuntak 2008; Snell 1948; Van Heekeren 1956), Vanuatu (Bedford et al. 2011; Bedford et al. 2009; Ravn et al. 2016), Papua New Guinea (Petchey et al. 2016), and Micronesia (Fitzpatrick and Boyle 2002). Variable interment type (i.e., supine, flexed, prone etc.), the removal of the head and other body parts after death, manipulation of the corpse and jar burials have been found in cemeteries with Austronesian artifacts dating ca. 3000–2000 BP in both Indonesia and the Pacific (Galipaud et al. 2016; Harris et al. 2016; Lloyd-Smith 2013; Valentin et al. 2010; Van Heekeren 1956). Although there is substantial cultural variability, the similarities in burial rituals within Austronesian cemeteries has been used to support the theory of a pan-regional belief system that spread throughout ISEA and the Pacific during the Neolithic (Galipaud et al. 2016; Oxenham et al. 2016; Valentin et al. 2015). There appears to be a connection between these "ritual" factors of burial with an ideological unity for Austronesian groups across the region.

Tooth ablation

A number of cultures, past and present, have purposefully removed teeth (ablation) for ritual and aesthetic purposes (e.g., Durband, Littleton, and Walshe 2014; Humphrey and Bocaege 2008; Inoue et al. 1995; Han and Nakahashi 1996; Merbs 1968; Morris 1998; Takenaka et al. 2008). The six front (anterior) teeth from the maxilla and mandible are favored for ablation because they are the area of the mouth that is observable to others when a person speaks or smiles (Milner and Larsen 1991). Ethnographic and historical records from some Southeast Asian and Pacific cultures indicate that tooth ablation was used as a marker of group identity, status, mourning the loss of a relative or to mark an important life event (such as marriage or coming of age), while also adding aesthetic appeal (e.g., Deacon 1934; Domett et al. 2013; Fox 1979; Muller and Guiart 1972; Nakahashi 2008; Nelsen, Tayles, and Domett 2001; Newton and Domett 2017; Pietrusewsky and Douglas 1993; Pietrusewsky et al. 2017; Speiser [1923] 1990; Tayles 1996; Willman, Shackelford, and Demeter 2016)

It has been suggested that tooth ablation found in Neolithic skeletal assemblages from China, the earliest dating to 6500 BP in the Shandong region, may have spread east to Japan (Han and Nakahashi 1996), and south to Taiwan (Blench 2008) and, possibly, Southeast Asia (Domett et al. 2013). It was previously suggested that the earliest evidence for tooth ablation in Southeast Asia was found at the Tam Hang site, Laos (Willman, Shackelford, and Demeter 2016), but the Pleistocene-era (15,700 BP) date for the site has now been revised (McColl et al. 2018) and tooth ablation does not appear before the Neolithic ca. 4500 BP at Tam Hang (F. Demeter pers. comm.). Domett et al. (2013) and Pietruswsky et al. (2017) discuss the possibility of tooth ablation spreading from southern China and Taiwan into Southeast Asia during the Neolithic, eventually reaching Cambodia (reviewed in Beavan and Halcrow 2013; Domett et al. 2013; O'Reilly, Domett, and Pheng 2008), Vietnam (Oxenham, Nguyen, and Nguyen 2002; Oxenham et al. 2009), Thailand (Sangvichien, Sirigaroon, and Jørgensen 1969; Tayles 1996), and Indonesia (Koesbardiati, Murti, and Suriyanto 2015; Koesbardiati and Suriyanto 2007; Suriyanto, Koesbardiati, and Murti 2012) where the practice is observed in some skeletal assemblages from the Neolithic, Bronze and Iron Ages (reviewed in Newton and Domett 2017). It should be noted that some of the evidence for ablation in the Bronze Age period in SEA is difficult to confirm because of the small sample of skeletal assemblages dating to this period and the assertion that tooth loss at the site of Noen U-Loke in the Iron Age could be the result of agenesis rather than ablation (Nelsen, Tayles, and Domett 2001).

Methods

Ablation identification and recording

Antemortem tooth loss (AMTL), or the loss of a tooth before the time of death, may result from disease (e.g., caries, abscesses and advanced periodontal disease) or accidental trauma and may be differentiated from failure to erupt and agenesis (Domett et al. 2013; Kinaston et al. 2019). When a tooth is lost for any reason before death, the alveolus (associated tooth socket) will resorb and, commonly, a gap (diastema) will remain that is a size comparable to the tooth lost. There may also be interproximal wear facets on teeth adjacent to the gap in cases of AMTL (Milner and Larsen 1991). If a tooth failed to erupt or was congenitally absent (agenesis or hypodontia) the diastema will commonly be obscured or closed by mesial drift, rotation or displacement of the nearby teeth (Nelsen, Tayles, and Domett 2001; Schuurs 2013).

Differentiating tooth ablation from other forms of AMTL, agenesis, and failure to erupt can be difficult in archaeological populations and relies on the identification of a number of variables, including: (1) the presence of a repeatable pattern of the loss of a specific tooth type in a population; (2) a generally symmetrical tooth loss in a skeletal sample; (3) the presence of a space in the alveolar bone where the tooth was removed; (4) general good dental health in the adjacent dentition; (5) possible fracture of the alveolar bone associated with the socket; and (6) possible presence of root fragments (Ikehara-Quebral et al. 2017; Merbs 1968; Milner and Larsen 1991; Nelsen, Tayles, and Domett 2001; Tayles 1996). Of these criteria, one of the most important is the good health of the dentition surrounding the observed AMTL. This is a major factor in differentiating ablation from AMTL from other etiologies, mainly pathologies such as caries, advance tooth wear, extramasticatory use of teeth, trauma, or hypodontia (reviewed in Palefsky 2019). For this study we follow the recommendation of Palefsky (2019, 700) that tooth ablation was identified as the most likely cause of the observed AMTL if "individuals exhibited no evidence of disease or unintentional dental alteration on the adjacent teeth or alveolar bone, (b) the dental arcade maintained space sufficient to accommodate the missing tooth, and (c) individuals did not have craniofacial or dental conditions associated with hypodontia".

All permanent teeth were recorded using the *Fédération Dentaire Internationale* (FDI) system (Keiser-Nielsen 1971). Non-adults with only deciduous dentition present were not included in the current analysis and there were no individuals with mixed dentition present. The presence or absence of a tooth or tooth socket was recorded using the following categories: present, lost antemortem, lost postmortem, agenesis, tooth erupting, and tooth impacted. All recording was conducted by RLK to eliminate the possibility of inter-observer error. Ideally, the entire anterior alveolar bone and associated dentition should be analyzed to assess the symmetry of tooth loss to determine possible "patterns" of tooth removal (e.g., the repeated ablation of the maxillary lateral incisors and canines). However, for seven individuals across all the samples, the differential preservation of skeletal remains necessitated that at least one half of the anterior maxilla (i.e., canine, lateral incisor, and central incisor all from the same side) to be present for an individual to be included in the current study. These individuals had posterior dentition present to assess for oral health. Tooth wear and oral health assessment was also conducted by RLK and will be reported in full in a future publication.

Age and sex estimation

The estimation of age-at-death was completed using standard methods, including late-fusing epiphyses, cranial suture closure, and pubic symphysis and auricular surface morphology (Buikstra and Ubelaker 1994). Adult individuals were categorized into age cohorts of older adolescent (16–19.9 years), young adult (20–34.9 years), mid adult (35–49.9 years), and old adult (50+ years). The age of non-adult individuals was estimated using standard methods of dental eruption and calcification, diaphyseal lengths, and epiphyseal fusion (Buikstra and Ubelaker 1994; Scheuer and Black 2000). Sex estimation for the adult individuals was completed using standard skull and pelvis sexual dimorphism methods described in Buikstra and Ubelaker (1994). Demographic information for the Pain Haka and Uripiv assemblages are reported in more detail in Galipaud et al. (2016) and Kinaston et al. (2014a). Unfortunately, sex estimation for the Melolo sample was not possible due to the loss of a number of the remains in the first half of the twetieth century. Age estimation as "adult" for the Melolo individuals analyzed in this study was based on the full eruption of the third molar and, in one instance, the extent of fusion of the sutures of the maxilla (Buikstra and Ubelaker 1994).

The skeletal assemblages

Pain Haka

The Pain Haka burial ground is located on the northeast peninsula of Flores Island (Figure 1), in the East Nusa Tenggara province of Indonesia. A total of 48 burials were discovered at the site, dating to between 3000 and 2100 BP (Table 1 and Galipaud et al. 2016). The site contained numerous Neolithic artifacts, including incised and appliqué red-slipped pottery, quadrangular stone and shell adzes, and shell jewelry. A full report of the excavation, burials, and artifacts is detailed in Galipaud et al. (2016) and Harris et al. (2016). For the current study, 15 adult (20+ years) or older adolescent (16–19.9 years) and one 13-year-old were analyzed (Table 2). These individuals had well preserved anterior maxillae, the majority of which (n = 13) had the alveolar process spanning from the right to left canines present. Three individuals (burials 20, 21D, and 46) had only the left or right side (an antimere) of the anterior maxilla present. Thirteen of the 16 individuals with maxillae also had the anterior mandible preserved that could be analyzed for the current study.

Melolo

The Melolo site is located in the township of Melolo on the eastern side of the island of Sumba in the East Nusa Tenggara Province of Indonesia (Figure 1). It is a large Neolithic urn burial site that has had a history of colonial excavations beginning in the early twentieth century (Koesbardiati et al. 2018; Snell 1948). The only early "scientifically" based excavation was conducted in 1939 by Dr. W.J.A. Willems who found a large number of pottery vessels (*tempayan* [jars], *periuk* [large bowls], *kendi* [pitcher/ewer]) associated with secondary interments, some with incised and appliqué decoration; shell beads, pendants and rings; and quadrangular stone adzes (cited in Snell 1948), all of which are known to be associated with Neolithic Austronesian populations. Another excavation was carried out in 1949 by A. Buhler, who found additional jar burials (Koesbardiati et al. 2018). From the available literature, only the skulls from Willems's excavation (labelled I-IV) and two previous excavations conducted by Professor Rodenwalt in 1923 (labelled 1-34) and Dr. Onvlee in 1936 (labelled A-K) have

Table 1. Radiocarbon dates for sites and burials with ablation.

Site	Sample	DM/M[1]	Lab code[2]	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C:N	CRA (yr BP)[3]	68% prob (cal BP)	95% prob (cal BP)	Cal ref[4]	Ref[5]
Pain Haka	Burial 21a	HBC/AMS	Wk-36560	−15.3	6.8	38.7	13.8	3.3	2246 ± 25	2331–2183	2339–2157	1	1
Pain Haka	Burial 22	HBC/AMS	Wk-36556	−16.4	8.9	32.3	11.3	3.4	2831 ± 25	2963–2882	3003–2859	1	1
Pain Haka	Burial 26	HBC/AMS	Wk-36558	−13.7	8.8	43.8	15.5	3.3	2588 ± 25	2750–2725	2760–2620	1	1
Pain Haka	Burial 48	HBC/AMS	Wk-41599	−15.8	7.8	41.9	14.6	3.4	2532 ± 20	2740–2540	2750–2500	1	1
Liang Bua	Sector IV	Char/GPC	GrN-14304						3390 ± 270			N/A	2
Lewoleba		Char/GPC	GrN-?						2990 ± 160			N/A	3
Melolo		Char/GPC	GrN-?						2870 ± 60			N/A	3
Liang Toge	N/A	HBC/AMS	MAMS-35084	−12.4	N/A	15.9	N/A	3.3	1128 ± 19	1058-986	1066-973	2	New
Liang Toge	N/A	HBC/AMS	MAMS-35085	−11.1	N/A	39.4	N/A	3.3	914 ± 19	902-791	911-786	2	New
Uripiv	Burial 16	HBC/AMS	WK-27490	−17.3	9.3	43.7	15.2	3.4	2440 ± 30	2370-2150	2700-2050	3	4
Uripiv	Burial 17	HBC/AMS	WK-27491	−17	9.3	43.9	15.5	3.3	2268 ± 30	2290-1970	2320-1900	3	4
Uripiv	Burial 19	HBC/AMS	WK-30884	−17.5	8.5	43.5	15.2	3.3	2530 ± 28	2670-2330	2720-2280	4	4
Uripiv	Burial 23	HBC/AMS	WK-30885	−14.4	9.4	42.9	15.2	3.3	2310 ± 33	2110-1920	2300-1850	4	4

[1]DM/M (dating material/method); HBC (Human bone collagen); Char (charcoal); AMS (Accelerator Mass Spectrometry); GPC (Gas Proportional Counting).
[2]Wk (Waikato Radiocarbon Dating Laboratory, Hamilton, New Zealand); GrN (Centrum voor Isotopenonderzoek, Groningen, Netherlands); MAMS (Klaus-Tschira-Archäometrie- Zentrum, Heidelberg, Germany).
[3]CRA (conventional radiocarbon age).
[4]Cal ref (reference for calibration): 1- OxCal v4.2.2 (Bronk Ramsey 2013) and IntCal09, Marine09 (Reimer et al. 2009); 2- IntCal13, Marine13 (Reimer et al. 2013) and Swisscal 1.0 (L. Wacker ETH- Zürich); 3- OxCal v3.10 (Bronk Ramsey 2005) and IntCal09, Marine09 (Reimer et al. 2009); 4- OxCal v4.1.7 (Bronk Ramsey 2010) and IntCal09 (Reimer et al. 2009).
[5]Ref (reference for dates): 1- Galipaud et al. (2016); 2- Roberts et al. (2009); 3- Atmosudiro (1994); 4- Kinaston et al. (2014).

Table 2. Total number of individuals with preserved maxillae and mandibles in each skeletal assemblage.

Site	PH max	PH mand	ML max	ML mand	LL max	LL mand	LB max	LB mand	UP max	UP mand
Adult Male	5*	3*			3	3	1	1	2	2
Adult Female	7*	6*			1	1	1	2	3	4
Adult ?S	3	3	5	6			1			1
Non-adult	1	1								
Total	**16**	13	**5**	6	**4**	4	**3**	3	**5**	7

?S (unknown sex); PH (Pain Haka); ML (Melolo); LL (Lewoleba); LB (Liang Bua); UP (Uripiv); max (whole or half anterior maxilla present); mand (whole or half anterior mandible present).
*One older adolescent (age 16–19.9 years) included in the count for each sex cohort.
Number of individuals with maxillae present are detailed in bold.

been reported in the literature (Snell 1948; Van Heekeren 1956). Unfortunately, the majority of these cranial remains and almost all of the postcranial remains from the Melolo site (a total of approximately 50 individuals) have been lost except for a small collection of material curated at Airlangga University in Surabaya, Indonesia. Pusat Penelitian Arkeologi Nasional - Puslit Arkenas (National Archaeological Research Center of Indonesia) conducted later excavations at the Melolo site from 1985–1988. Charcoal was collected from the same layers as the Neolithic pottery during these later excavations and ^{14}C dated to 2870 ± 60 BP (Centrum voor Isotopenonderzoek, Groningen, Netherlands) (Atmosudiro 1994) (Table 1).

The occurrence of tooth ablation has been addressed at Melolo before (Koesbardiati, Murti, and Suriyanto 2015; Koesbardiati and Suriyanto 2007; Suriyanto, Koesbardiati, and Murti 2012), but ablation was reanalyzed in this study to avoid inter-observer error. For this study, five adult individuals with a full or half anterior maxilla present and six individuals with a full or half anterior mandible present were analyzed (Table 2). All mandibles and maxillae included in this analysis were from different individuals.

Lewoleba

The Lewoleba cemetery site is located on Lembata Island, East Flores, Nusa Tenggara Timur province, Indonesia (Figure 1). Excavations at the Lewoleba site in 1961 by T. Verhoeven and Lie Goang Liong led to the discovery of five adult individuals at site LLI, fragments of infant bones in an urn and a calvarium fragment at site LLII and a few human bone fragments at site LLIII; all human burials and bones from Lewoleba were found in a lithified sandstone sediment (layer D) (Bintarti 2000; Liong 1964). Later excavations near site LLI were conducted by Puslit Arkenas in 1984 and 1985 (Bintarti 1986). During these later excavations, charcoal from the same layer the skeletons were found in (Layer D) was sampled and ^{14}C dated to 2990 ± 160 BP (Centrum voor Isotopenonderzoek, Groningen, Netherlands) (Atmosudiro 1994) (Table 1). No metal was found during any of the excavations of Lewoleba. A variety of jars (*periuk* and *buli buli* [little jars]) and plain and decorated sherds, including impressed scallop, incised and face motifs, support the Neolithic date for the site (Bintarti 1986, 2000; Liong 1964). The research that has been conducted on the Lewoleba remains includes an anthropological assessment of the skeletons (Liong 1965), three publications detailing tooth ablation in the assemblage (Koesbardiati, Murti, and Suriyanto 2015; Koesbardiati and Suriyanto 2007; Suriyanto, Koesbardiati, and Murti 2012) and one publication focused on the presence of non-specific indicators of stress (linear enamel hypoplasia, cribra orbitalia and porotic hyperostosis) (Koesbardiati et al. 2018). The five Lewoleba crania from site LLI are currently curated at the University of Airlangga, Surabaya. Of the total assemblage, four individuals had both maxillae and mandibles available for analysis (Table 2).

Liang Bua

The Liang Bua cave site is located 11 kilometers away from Ruteng, the capital city of the West Manggarai Regency of Flores (Figure 1). Although the site is best known for the discovery of *Homo floresiensis* (Morwood and Jungers 2009; Sutikna et al. 2016), the site also contains Neolithic deposits, which were first excavated in 1965 by T.H. Verhoeven. During this excavation, six skeletons were discovered. Only five skulls from this excavation are still in existence today and are curated by the University of Airlangga, Surabaya (Koesbardiati et al. 2018; Suriyanto, Koesbardiati, and Murti 2012). These five skulls were available for analysis in this study.

Later excavations at the site from 1978–1989 were conducted by Puslit Arkenas and nine skeletons were discovered during these expeditions. Two of the skeletons had skulls, which are now curated at the Laboratory for Biological Anthropology and Paleoanthropology, University of Gadjah Mada, Yogyakarta (Koesbardiati et al. 2018; Morwood et al. 2009; Soejono 1980, 1985), but these were not available to assess for the current study. A charcoal sample from Neolithic deposits associated with the human skeletons was collected during the later excavations and ^{14}C dated to 3390 ± 270 BP (Centrum voor Isotopenonderzoek, Groningen, Netherlands) (Atmosudiro 1994; Roberts et al. 2009) (Table 1). In both the earlier and later excavations, the burials were found with material culture associated with the Neolithic and Proto-Metallic periods, including plain and decorated pottery (*periuk*, *kendi*, *buli buli*, and *tutup* [lid]), flaked adzes, bone tools, pig tusks and a bronze axe (Morwood et al. 2009; Soejono 1980, 1985).

The occurrence of tooth ablation has been addressed at Liang Bua before (Koesbardiati, Murti, and Suriyanto 2015; Koesbardiati and Suriyanto 2007; Suriyanto, Koesbardiati, and Murti 2012). Only three of the five individuals that were available for analysis had enough maxillary dentition (burials 2, 3, and 6) to be included in this study. Two of these individuals (burials 3 and 6) and an additional individual (burial 1) had enough mandibular dentition to be included in this study (Table 2).

Uripiv

Uripiv is a small island ($<2\,km^2$) located off the northeast coast of Malekula in northern Vanuatu (Figure 1). Burials were found dating to the earliest occupation of the island during the Lapita (2800–2500 BP), post-Lapita (2500–2000 BP), and protohistoric (300–150 BP) periods (Bedford et al. 2011; Kinaston et al. 2014a). The diet and human mobility patterns of all the individuals buried in the cemetery on Uripiv has been addressed using isotope analysis and oral health indicators (Kinaston et al. 2014a;

Table 3. Maxillary tooth ablation patterns and total number of individuals affected.

	Anterior maxillary tooth ID						Site				
Pattern #	13	12	11	21	22	23	Pain Haka	Melolo	Lewoleba	Liang Bua	Uripiv
1	A	A			A	A	5		2	2	
2		A			A	A	1				
3	A				A	A	1				
4	A	A			A				1		
5	A	A	A		A	A	1				
6	A	A	A	A	A	A	1				
7	A	A		NP	A	A		1			
8	A	A		NP	NP	NP	1	1	1		
9	A				NP	NP				1	
10	NP	NP			A	A	1				
11	NP	NP	NP		A	A		1			
12	NP	NP	NP			A		1			
13	NP	NP	NP		A		1				
14			A	A							4
						n/Abl	12	4	4	3	4
						N	16	5	4	3	5
						%A	75	80	100	100	80

NP = Tooth and alveolar socket not present; A = AMTL; n/Abl = number of individuals affected by ablation; N = total number of individuals with observable maxillae; %A percent of individuals affected by ablation in each group.

Kinaston et al. 2016b). The latter study noted antemortem tooth loss (AMTL) in the post-Lapita and Lapita samples that is consistent with the practice of ritual tooth ablation. All of the individuals with available dentition were analyzed for the current study. This included four individuals (one later Lapita and three post-Lapita) with anterior maxillae and one post-Lapita individual with the full anterior maxillary dentition (canines and incisors). All individuals with maxillae also had mandibles available for analysis, and two additional burials (a post-Lapita female and adult of unknown sex) only had mandibles available for analysis (Table 2).

Results

The total number of individuals analyzed for each site is presented in Table 2. High rates of anterior AMTL were observed for the maxillary dentition of the individuals from all five sites (Table 3). No anterior mandibular AMTL was identified in the skeletal assemblages with the exception of one individual from the Uripiv site who displayed the antemortem loss of all four mandibular incisors. As a result of the lack of any mandibular AMTL and, correspondingly, any mandibular ablation at the four Indonesian sites, the remaining results and discussion will mainly focus on maxillary AMTL and ablation.

In all cases of anterior maxillary AMTL, there was: 1) little or no pathology present on the adjacent teeth and alveolar bone; 2) adequate space in the remodeled alveolar bone for a tooth, supporting that a tooth had been removed before death and the socket had healed (e.g., not agenesis or failure to erupt); 3) regularly symmetrical loss when two antimeres were present; and 4) a repeatable pattern of loss within each skeletal sample. The evidence, therefore, supports the assessment that the high rate of anterior AMTL in these assemblages was a result of intentional tooth ablation and not a result of the pathological loss of the tooth or genetic agenesis.

Table 4. Pain Haka tooth ablation pattern prevalence rates per sex cohort.

	Anterior maxillary tooth ID						Sex				
Pattern	13	12	11	21	22	23	M	F	?S	n=	%P
1	A	A			A	A	1	4		5	41.7
2		A			A	A	1			1	8.3
3	A				A	A	1			1	8.3
4	A	A			A						0.0
5	A	A	A		A	A			1	1	8.3
6	A	A	A	A	A	A	1			1	8.3
7	A	A		NP	A	A					0.0
8	A	A		NP	NP	NP			1	1	8.3
9	A				NP	NP					0.0
10	NP	NP			A	A	1			1	8.3
11	NP	NP	NP		A	A					0.0
12	NP	NP	NP			A					0.0
13	NP	NP	NP		A				1	1	8.3
14			A	A							0.0
						n/Abl	5	4	3	12	
						n/O	5	7	3	15*	
						%A	100	57	100	80	

NP = Tooth and alveolar socket not present; A = AMTL; M = Male; F = Female; ?S- Unknown sex; n = total number individuals affected; %P = percent of individuals with each pattern type; n/Abl = number of individuals affected by ablation; n/O = total number of individuals with observable maxillae; %A percent of individuals affected by ablation in each group.
*note that this count excludes the 13-year-old individual.

The 14 patterns noted in the following discussion (see Table 3) take into account the variation in ablation patterns and the differential preservation observed across the skeletal assemblages. Patterns 2–13 appear to be associated with Pattern 1, the ablation of the maxillary canines and lateral incisors, and are found in the Indonesian skeletal samples. Pattern 14 is the ablation of only the maxillary central incisors, which is only observed in the Uripiv skeletal assemblage from Vanuatu.

Pain Haka

At the Pain Haka site, 75% (n = 12) of the 16 individuals with observable maxillae displayed evidence for ablation. The three individuals with no evidence for ablation were female, two were from the young adult age group, and one was an older adolescent aged 16-19.9 years. There was only one juvenile with an observable maxilla (burial 47B, aged 13 years) and this individual did not have any evidence for AMTL. The most common pattern of ablation at the Pain Haka site was the symmetrical removal of the maxillary lateral incisors and canines (Pattern 1, 41.7%) (Table 4; Figure 2). The other ablation patterns observed were typically modifications of Pattern 1 (e.g., one remaining lateral incisor or canine) or Pattern 1 with one or both of the central incisors removed (labelled Patterns 5 and 6). The individuals that were affected on an antimere of the maxilla had only this aspect of the maxilla available for analysis, but the pattern of AMTL (Patterns 8-13) was consistent with the other affected individuals. There was no AMTL observed on the anterior mandibular dentition.

Males displayed higher rates of tooth ablation (5/5, 100%) compared with females (4/7, 57%) in the Pain Haka sample, and males displayed more variable patterns compared with females (Table 4). Although the sample size is very small to draw inferences, there

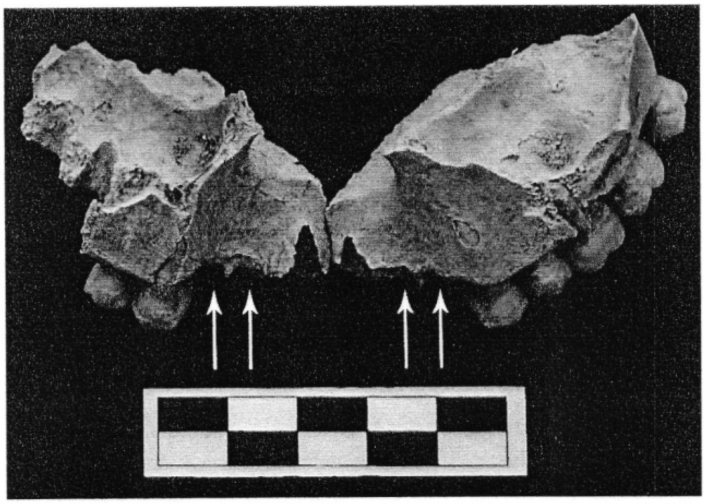

Figure 2. Pain Haka burial 48 (young adult female), evidence for ablation of the right and left maxillary lateral incisors and canines (white arrows). Note that both maxillary central incisors have been lost postmortem.

may have been an increase in the occurrence of ablation with age during adulthood; adult individuals from the young adult (4/6, 67%) and older adolescent age cohorts (1/2, 50%) were less affected compared with the mid and old age cohorts (7/7, 100%) (Table 5). It may be of note that the three adult individuals who showed no sign of ablation were either young adult or older adolescent females.

Melolo

The Melolo skeletal sample included five individuals with anterior maxillae observable (full or antimeres) for analysis and 80% (n = 4) displayed evidence for tooth ablation. Similar to the Pain Haka sample, the ablation followed the loss pattern of Pattern 1 (i.e., the removal of lateral incisors and canines) (Table 3) expressed as Patterns 7, 8, 11, and 12. Six mandibles with complete anterior alveolar bone (n = 4) or antimeres (n = 2) were available for analysis and none of these displayed evidence for ablation. As discussed, age or sex estimates could not be estimated for this sample so it is not possible to postulate on the relation between ablation and these variables. Photos of two, now lost, crania from the Melolo sample (Melolo IV and VII) also indicate that these individuals likely exhibit Pattern 1 in the maxillae (Snell 1948, 6-7), but as this could not be confirmed by macroscopic analyses, these individuals were not included in the current study.

Table 5. Pain Haka tooth ablation pattern prevalence rates per age cohort.

	Anterior maxillary tooth ID						Age					
Pattern	13	12	11	21	22	23	AD	YA	MA	OA	n=	%P
1	A	A			A	A		2	2	1	5	41.7
2		A			A	A			1		1	8.3
3	A				A	A	1				1	8.3
4	A	A			A							0.0
5	A	A	A		A	A		1			1	8.3
6	A	A	A	A	A	A				1	1	8.3
7	A	A		NP	A	A						0.0
8	A	A		NP	NP	NP			1		1	8.3
9	A				NP	NP						0.0
10	NP	NP			A	A		1			1	8.3
11	NP	NP	NP		A	A						0.0
12	NP	NP	NP			A						0.0
13	NP	NP	NP		A				1		1	8.3
14			A	A								0.0
						n/Abl	1	4	5	2	12	
						n/O	2	6	5	2	15*	
						%A	50	67	100	100	80	

NP = Tooth and alveolar socket not present; A = AMTL; AD = Adolescent (16-19.9 years); YA = Young Adult (20-34.9 years); MA = Mid Adult (35-49.9 years); OA = Old Adult (50+ years); n = total number individuals affected; %P = percent of individuals with each pattern type; n/Abl = number of individuals affected by ablation; n/O = total number of individuals with observable maxillae; %A percent of individuals affected by ablation in each group.

*note that this count excludes the 13-year-old individual.

Lewoleba

There were four individuals with both the maxillary and mandibular anterior dentition present. All four displayed AMTL on the maxillary, but not the mandibular, dentition. Two of these individuals exhibited Pattern 1, the loss of both the maxillary lateral incisors and canines, one individual displayed Pattern 4 (the loss of the maxillary laternal incisors and the right canine) and one individual displayed Pattern 8 (right antimere of the maxilla present with the loss of the lateral incisor and canine) (Table 3).

Liang Bua

All three individuals with adequately preserved maxillary dentition displayed AMTL, two exhibiting Pattern 1 (Figure 3) and one exhibiting Pattern 9 (the loss of only the right maxillary canine) (Table 3). No AMTL was observed on the mandibular dentition.

Uripiv

At the Uripiv site, 80% of individuals who had a complete anterior maxilla displayed tooth ablation in the form of the symmetrical loss of the central incisors (Pattern 14, n = 4/5) (Figure 4). One of these individuals (burial 19) was a female from the late Lapita period, whereas the others were a female (burial 16) and two males (burials 17 and 23) from the post-Lapita period. One female post-Lapita individual (burial 2) in the Uripiv sample displayed a full set of anterior maxillary dentition in the grave and therefore could not have lost a tooth before death unless the tooth was saved and it was buried with them in anatomical position after they died. Although the alveolar bone of the mandible and left anterior and right posterior maxilla was preserved for burial 2,

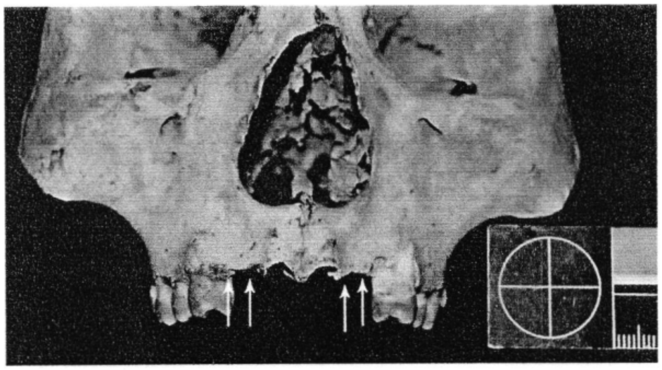

Figure 3. Liang Bua burial 6 (young/mid adult female), evidence for ablation of the right and left maxillary lateral incisors and canines (white arrows). Note that both maxillary central incisors have been lost postmortem.

the anterior alveolar bone of the right maxilla was not preserved enough to assess AMTL, but the presence of these teeth *in situ* indicate that they were not lost before death. Of the seven individuals with a full anterior mandibular dentition for analysis, only burial 33 (post-Lapita, unknown sex) displayed AMTL (all four mandibular incisors).

Discussion

Ablation in Indonesia

This study is the most comprehensive analysis of Neolithic skeletal assemblages found in Indonesia. Although the sample sizes are small, these assemblages represent almost all the known Neolithic-age cemetery samples from the region and can therefore provide direct evidence of the lives of these people during the Austronesian expansion. The presence of tooth ablation at the Pain Haka, Melolo, Lewoleba, and Liang Bua sites suggests that this practice was common for Austronesian populations in eastern Indonesia during the Neolithic. At all the sites, tooth ablation occurred in adults and older adolescents, suggesting that the ritual may have been associated with some type of life event (e.g., marriage or coming of age). This is further supported by the fact that the four individuals at Pain Haka who did not display evidence for tooth ablation were either young adults or adolescents. However, the sample sizes for non-adult individuals were small and age could not be estimated for a number of the individuals assessed, especially from the Melolo sample. Therefore, it is not possible to determine if non-adult individuals underwent ritual tooth ablation in these communities.

The earliest secure dating for the practice of ablation in Indonesia is from the Pain Haka site. Bone collagen from three individuals with evidence for ablation and one individual (burial 21a) who was interred in a multiple burial with an individual with ablation (burial 21d) have been directly dated (Galipaud et al. 2016). The earliest, burial 22,

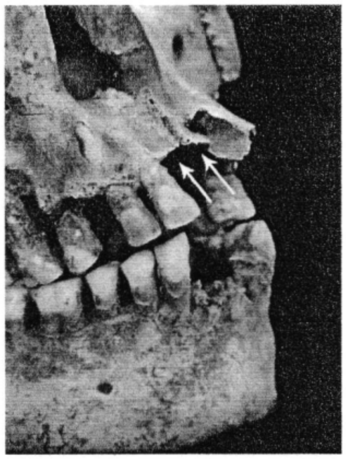

Figure 4. Uripiv burial 23 (post-Lapita male), evidence for ablation of the right and left maxillary central incisors (white arrows). Note that the left maxillary lateral incisor and canine have been lost postmortem.

dated to 3003–2859 cal BP (Wk-36556) and the other individuals were interred throughout the use period of the cemetery (ca 3000–2100 BP): burial 26 (2760–2620 cal BP [Wk-36558]), burial 48 (2750–2500 cal BP [Wk-41599]), and burial 21a (2339–2157 cal BP [Wk-36560], the individual who was interred with burial 21d) (Table 1).

The absolute dates from Liang Bua (3390 ± 270 BP), Lewoleba (2990 ± 160 BP), Melolo (2870 ± 60 BP) sites have not been calibrated (Table 1) and direct bone dates would have been preferable, but were not available. Importantly, the material culture at the three sites (plain and decorated pottery [incised and applique], shell jewelry, quadrangular and flaked stone adzes), support that these cemetery sites date to the Neolithic (ca. 3500–2000 BP). The only evidence for metal at any of the sites being a bronze adze at Liang Bua, suggesting this site use spanned from the Neolithic to the Proto-Metallic period (Morwood et al. 2009; Soejono 1980, 1985). The presence of tooth ablation in these four cemetery sites across the Lesser Sunda Islands establishes that the practice was present during the initial Austronesian expansion in the region. Tooth ablation has also been observed at the Neolithic and Metal Age Lambanapu site (T. Simanjuntak pers. comm.), located approximately 50 km west of Melolo on Sumba Island (Handini et al. 2018), indicating a possible continuation of the practice into the proceeding Metallic Age in eastern Indonesia, at least on Sumba.

Today, tooth ablation is not practiced in eastern or other areas of Indonesia, but other types of dental modifications, including filing and blackening, for aesthetic purposes has been recorded in modern times in Timor, Lembata and nearby islands in eastern Indonesia (Koesbardiati, Murti, and Suriyanto 2015; Liong 1964). Intentional filing of teeth has only been observed at one prehistoric site in Flores, Liang Toge, dating to 1066–786 cal BP (MAMS-35084 and MAMS-35085) (Table 1). In the western islands of Indonesia, filing of teeth is more widespread and found at prehistoric sites in Java (Leran and Binangun) and Bali (Semawang and Gilimanuk) (Koesbardiati, Murti, and Suriyanto 2015). In Bali, tooth filing is practiced in modern times as part of a Hindu tradition to help people refrain from lust (Koesbardiati, Murti, and Suriyanto 2015), but clearly the prehistoric occurrence of the practice pre-dated the arrival of Hinduism. Tooth filing also occurs in India (Kennedy, Misra, and Burrow 1981) so it is difficult to ascertain if whether, on Bali, this tradition was carried over from an earlier period, brought with Hinduism, or both (Artaria 2017). Other reports from Bali detail filing and blackening as a coming of age ritual, which also acts to differentiate human teeth from dog and monkey teeth as these animals are perceived as unhygienic (Forge 1980; Mower 1999). In Borneo, Dyak tribes file and blacken their teeth as a sign of status (Jones 2001). It has previously been suggested that tooth ablation in eastern Indonesia represents one of the earliest forms of dental modifications in the country and that the occurrence of filing and blackening in the western islands is a result of a more recent migration of people and culture (Koesbardiati, Murti, and Suriyanto 2015). Our results suggest that tooth ablation was widespread among Neolithic communities in eastern Indonesia and, at least in these assemblages, no other types of tooth modification were observed, supporting the notion that it was one of the earliest forms of tooth modification in the region.

Ablation in the Pacific Islands

The tooth ablation observed in the Uripiv skeletal sample (ca. 2800–2000 BP) is the earliest evidence for the practice in the Pacific Islands. Beginning around 3000 BP, Austronesian Lapita populations were the first people to settle Vanuatu and the other Pacific Islands of Remote Oceania (Kirch 2010). New genetic evidence from the Uripiv site and modern ni-Vanuatu people has shown an unprecedented genetic replacement in Vanuatu from Near Oceania while maintaining Austronesian languages (Posth et al. 2018). The late Lapita individual with evidence for ablation (burial 19) was direct dated to 2720–2280 cal BP and the association of this individual with later Lapita pottery indicates a date closer to 2600–2500 BP. The other individuals with evidence for ablation who were directly dated (burials 16, 17 and 23) were interred during the post-Lapita period (ca. 2500–2000 BP) (Table 1). The transition between the late Lapita and post-Lapita periods (ca. 2500–2400 BP) is the estimated time that admixture between Austronesian Lapita populations and Papuan people, likely arriving from the Bismarck Archipelago, occurred on Uripiv (Posth et al. 2018). There were no adult individuals found at Uripiv that date to the earlier Lapita period (ca. 2800–2600 BP) to determine if the practice of tooth ablation arrived with the first Austronesian settlers to the island. Therefore, there are three possible explanations for the origin of prehistoric ritual ablation on Uripiv: (1) the practice was brought with Austronesian Lapita settlers; (2) it arrived from the Bismarck Archipelago with Papuan migrants ca. 2500–2400 BP; or (3) it was an indigenous cultural development in northern Vanuatu.

To determine if tooth ablation arrived with Vanuatu's first Lapita settlers, we would need to find evidence for the practice dating to pre-2500 BP at sites associated with

Lapita pottery. Tooth ablation has not been observed in the limited number of other Lapita-associated cemetery samples discovered to date, including Watom (Bismarck Archipelagos, PNG), Teouma (Efate Island, central Vanuatu) and Vao (northeast Malekula, Vanuatu) (Kinaston et al. 2016b). However, it is difficult to determine if this is a result of poor preservation, lack of skulls, or the small sample size of these other assemblages, essentially absence of evidence, at other Lapita cemeteries. Poor preservation of the anterior dentition of the individuals in the Vao (northern Malekula) Lapita skeletal assemblage meant that ablation could not be assessed at the site. No evidence for AMTL was observed in the Lapita-associated Watom skeletal assemblage ($n = 4$ individuals with well-preserved dentition) dating to 2700–2500 BP (mid-late Lapita periods) (Kinaston et al. 2016b).

Absence of evidence of tooth ablation resulting from specific burial practices is an inherent limitation of understanding the possible distribution of the practice in Lapita populations. Although more than 100 individuals were found at the Teouma Lapita site on Efate Island, Vanuatu, all the skulls were removed after death and the only crania and mandibles found were interred as secondary burials with other individuals (Bedford et al. 2010). Of these seven crania and five mandibles (only burial 17 had both a mandible and maxilla), burial 10B was the only individual with evidence of anterior AMTL (left upper central incisor). Burials 2a and 2b from the post-Lapita burials at Teouma (Area 7c, ca. 2500 BP) displayed the antemortem loss of the upper central incisors (burial 2a) and the right central incisor (burial 2b) (Kinaston et al. 2016b). The overall small sample size and poor dental health of burial 2a mean that it is impossible to positively identify if ablation was the cause for the AMTL in this sample, but it remains a possibility. Based on cranial morphology, it has been suggested that the post-Lapita individuals from Teouma were of Papuan ancestry and represented a more recent migration into the region (Valentin et al. 2014), a theory supported by the recent genetic evidence of early Austronesian and later Near Oceanic settlement of Remote Oceania (Posth et al. 2018; Skoglund et al. 2016).

To identify Near Oceanic roots for the ritual ablation observed in the Uripiv assemblage, we would need to find evidence for the practice in prehistoric cemetery samples from Papua New Guinea or the Solomon Islands, of which there are very few (and no example of the practice could be found in the ethnographic records for the region). The only known prehistoric cemetery discovered to date in the Bismarcks, on Watom Island (discussed above where there is no evidence for ablation), dates to the Lapita period and may include Austronesian individuals admixed with Papuan populations as evidenced by biodistance study of mandibles from the site (Pietrusewsky et al. 2014) (aDNA analyses are currently underway). There is also considerable complexity in understanding cultural roots because of the settlement history of the region. Non-Austronesian speaking people lived in Near Oceania for tens of millennia before Lapita populations came into the region (Spriggs 1997; Summerhayes et al. 2010a) and the Bismarck Archipelago is a region known for Lapita settlement sites from ca. 3300 BP (Summerhayes et al. 2010b; Summerhayes 2001). Vessel form and design motifs from Middle Lapita sites in Vanuatu parallel those found in the Arawe Islands and Mussau Group in the Bismarck Archipelago (Bedford and Spriggs 2018; Specht 2007) and indicate cultural links between the regions. Other types of cultural links between northern

Vanuatu and the Bismarck Archipelago, especially the Arawe Islands in southern New Britain, have been posited since the early twentieth century in the form of human skull binding and raising highly-revered "tusker" pigs (pigs with exceptionally long and round upper canines due to the removal of the lower canines) (reviewed in Layard 1942). Therefore, the proposition that populations with Papuan ancestry from the Bismarck Archipelago may have brought tooth ablation to northern Vanuatu does not preclude that the practice did not have an Austronesian influence in Near Oceania.

It is possible that, in northern Vanuatu, the practice of tooth ablation was an indigenous cultural development. To the authors' knowledge, tooth ablation has not been observed in any other prehistoric skeletal samples from sites dating to the Lapita period or later in the Pacific Islands, except for much later sites in Hawaii and possibly Micronesia. Some of the only published documentation of tooth ablation in skeletal samples from the Pacific details the practice occurring in Hawaii during the late prehistoric/early historic periods (Chappel 1927; Pietrusewsky and Douglas 1993). From ethnographic comparisons, it was suggested that this might have been a mourning ritual associated with the rise in power of the *ali'i* (hereditary noble caste) (Pietrusewsky and Douglas 1993). One possible case of mandible tooth ablation was observed in a male from a skeletal assemblage from a pre-contact Chamorro site on Guam (Apurguan) and a number (9/19, 47.4%) of other individuals in the sample displayed AMTL of the maxillary or mandibular incisors without any other tooth type lost (Douglas, Pietrusewsky, and Ikehara-Quebral 1997). Tooth modification, in the form of incising and filing, has also been observed in late prehistoric and historic populations from the Marianas Islands in Micronesia (reviewed in Ikehara-Quebral and Douglas 1997). However, it is difficult to assess if the lack of tooth ablation in Lapita and post-Lapita associated individuals is actually a result of a lack of well-preserved and well-researched skeletal assemblages from this period (for a review see Clark et al. 2017; Kinaston and Buckley 2013; Pietrusewsky 2005).

Interestingly, the only ethnographic accounts of ritual tooth ablation in the Western Pacific document the practice in a number of communities in northern and north-central Vanuatu well into twentieth century (Deacon 1934; Fox 1979; Layard 1942; Muller and Guiart 1972; Speiser [1923] 1990). According to Speiser ([1923] 1990) the custom of ritual tooth removal was only performed on girls after their anterior permanent teeth had erupted (7–8 years of age) and adult women; in all cases only the upper central incisors were extracted, which are the same teeth that were ablated in the Uripiv skeletal sample. The practice had a relatively narrow distribution across Vanuatu spanning "eastern Santo, the west coast of Big Bay, throughout Malekula, with the exception of the eastern part north of Uripiv, and perhaps Epi" (Speiser [1923] 1990, 162).

In the districts of Seniang (southwest Malekula) and Lagalag (spanning the isthmus of northern Malekula) tooth ablation of the central maxillary incisors was practiced as part of a grading system associated with a secret woman's society (*Lapas* in Seniang and *Langambas* in Lagalag) (Deacon 1934). In Seniang, the removal of an adolescent girl's teeth was performed so she could become eligible to enter the lowest grade within the *Lapas* society. This was also a social marker of her transition from girl to woman and made her eligible for marriage. In Lagalag, the ritual removal of central maxillary incisors usually occurred two to three years after a woman was married and allowed her to become eligible to the *Langambas* (Deacon 1934). In Lambubu, central-eastern Malekula, both women and girls underwent ritual tooth ablation of the upper central incisors as a means to acquire social prestige and, through holding successive feasts, obtained honorific titles associated with increases in social standing (Deacon 1934). In all three regions, Seniang, Lagalag, and Lambubu, the teeth were removed by having the woman bite down on a stick, while the teeth were extracted by a practitioner using a stone to strike a stick into the tooth.

Tooth ablation of the upper central incisors was also performed on girls of the Big Nambas and Small Nambas tribes of northern Malekula. It was believed to increase fertility and was performed on the women of the Big Nambas at the time of marriage and on women in the Small Nambas as part of a ritual to increase rank and social status (Fox 1979; Muller and Guiart 1972).

Ablation in the context of the Austronesian Diaspora

The origin of the Austronesian practice of tooth ablation in ISEA is unknown, but the earliest evidence for the practice in Neolithic Asia is found at Chinese sites dating to 6500 BP (Han and Nakahashi 1996). A survey of multiple skeletal assemblages from the eastern and south-eastern regions of coastal China suggested the practice might have originated in the Shandong-North Jiangsu region and spread to other areas, including Taiwan (Han and Nakahashi 1996). Tooth ablation is also observed in prehistoric skeletal samples from Japan (e.g., Kusaka et al. 2008; Temple, Kusaka, and Sciulli 2011). However, in general, the Japanese pattern of tooth ablation is much more variable than that found in China and, at its height in the late Jomon period, occurred ~2000 years later (Han and Nakahashi 1996).

Tooth ablation (primarily of the maxillary lateral incisors and canines) has been found at a number of Neolithic sites across Taiwan (reviewed in Pietrusewsky et al. 2013; Pietrusewsky et al. 2017). Ethnographic accounts detail the widespread occurrence of tooth ablation in Taiwan, suggesting that the practice survived into the modern period (Pietrusewsky et al. 2017). The presence of ablation in Neolithic and later populations from Taiwan and the fact that tooth ablation was still practiced by Austronesian-speaking populations from Taiwan during the ethnographic present could signify that tooth ablation was an important and enduring aspect of Austronesian culture on the island.

As noted, on the basis of Bulbeck's (2008, 34) criteria for evaluating ISEA maritime networks, the widespread distribution of tooth ablation in ISEA and, possibly, into the Pacific could be considered a novel (bio)archaeological phenomenon that is "evidence of large-scale interaction and potentially a diaspora". Throughout ISEA and, possibly, in early Pacific populations, ritual tooth ablation appears to have been an important part of the Neolithic cultural package that included an Austronesian language and new forms of pottery, tools, jewelry, plants, and animals (Bulbeck 2008; Spriggs 2011). The similarities observed between burial ritual in ISEA and the Pacific provide evidence for a pan-regional belief system of Austronesian cultures during the Neolithic (Galipaud et al. 2016; Harris et al. 2016). Tooth ablation may be evidence for ritual behavior associated with this belief system that involved the living members of prehistoric Austronesian communities. Tooth ablation is a highly visible body modification that would also immediately signal group identity, a potential benefit to highly mobile groups moving through new landscapes and for the assimilation of people already resident in these regions. However, it is also possible the exact reasons for tooth ablation have changed over time and between regions as cultural expression is not static.

If the practice of tooth ablation did arrive in Uripiv with the earliest Lapita settlers or Papuan migrants influenced by Austronesian traditions in the Bismarck Archipelago, the change in the ablation pattern to the maxillary central incisors from the pattern observed in ISEA (maxillary lateral incisors and canines) may mirror the patterns observed in diverging styles of Lapita pottery (Chiu 2015) and tattooing tools (Clark and Langley 2019; Torrence et al. 2018) in the Pacific—as communities became established, new behaviors may have developed over time to differentiate themselves. At least in two areas, Taiwan and Vanuatu, the practice of tooth ablation appears to have been maintained over the succeeding millennia by Austronesian speaking communities, attesting to the enduring cultural importance of this ritual.

Conclusions

This study suggests that ritual tooth ablation was an important and highly visible aspect of Austronesian culture during the Neolithic in ISEA. As discussed, it is difficult to extrapolate the exact reasons ritual tooth ablation was performed in the past, but ethnographic accounts in the ISEA and Pacific indicate that coming of age, marriage, fertility, status increases, and mourning are all possibilities. It is also difficult to pinpoint the exact origin of the practice—although China has been proposed — (Han and Nakahashi 1996) and it may well be that there were multiple influences on different island Austronesian communities. However, the occurrence of tooth ablation in relatively contemporary sites across such a large geographic area suggests that the practice was part of the Neolithic cultural package that spread across ISEA and possibly entered into the Pacific. We propose that tooth ablation represents a cultural behavior associated with a pan-regional, Austronesian belief system, at least in ISEA.

The occurrence of tooth ablation at the late Lapita and post-Lapita site of Uripiv is the earliest evidence of the practice in the Pacific. From the current evidence, it is possible that the practice of tooth ablation was either brought into the Pacific with Lapita voyagers, was introduced to Vanuatu from the Bismarck Archipelago around 2500–2400 BP, or it was an indigenous development in northern Vanuatu. Interestingly, ritual tooth ablation of the same pattern observed in the prehistoric individuals from Uripiv was still practiced across much of Malekula and parts of other north-central and northern islands in Vanuatu into twentieth century, indicating the possible continuity of an enduring Austronesian cultural tradition over two and a half millennia, similar to that seen in Taiwan (Pietrusewsky et al. 2017).

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