







The ancient people of Balinese: a study of health status based on paleopathology remains

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ABSTRACT: Humans have been constantly exposed to the environment in their daily activities, which may result in some pathological changes. Paleopathology research is rare, particularly on ancient humans who lived in Bali, Indonesia. This research is intended to gain more insight into the history of diseases and the community in the past to assist future health researchers. This study was conducted to understand variation in disease among the ancient populations in Bali, Indonesia. The study examines skeletons from the Gilimanuk, Semawang, and Pacung Sembiran sites in Bali, Indonesia, collected from 1964 to 2008. A total of 336 individuals were identified, including 63 adult males, 75 adult females, and 56 adults whose sex could not be determined. In addition, 142 children were included in the analysis. The examination of the individuals revealed the presence of various dental pathological changes, such as caries and enamel hypoplasia, as well as periodontitis. Furthermore, several bone-related diseases and abnormalities were identified, such as osteophytes, fractures, porotic hyperostosis, and spina bifida occulta. Available evidence suggests a similarity in the types of pathological changes among the ancient populations of Gilimanuk, Semawang, and Pacung Sembiran. While a comprehensive explanation of the paleopathological variations observed in these populations necessitates further investigation, the present findings hold considerable value for medical experts and anthropologists seeking to better understand patterns of disease distribution among ancient Indonesian populations.

KEY WORDS: ancient, population, teeth, skeleton, paleopathology.



Original article

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Introduction

Life in the past is a considerably compelling point of discussion. The period before the 4th century AD was the ancient period, as indicated by the discovery of inscriptions in Kutai of East Kalimantan (Wiradnyana 2010), which served as the demarcating line of the historical and non-historical period in Indonesia. Just as anatomy and forensic medicine seek to answer questions of the present, paleopathology also uses human remains as research material to reconstruct life in the past to obtain a better understanding of the present (Roberts and Manchester 2005). This is helped by a large number of ancient (before 4th century) human bone remains found in Indonesian regions, such as in Gilimanuk (Bali), Semawang (Bali), Plawangan (Java), Sumatra (Aceh), Sulawesi (Makasar), Kalimantan (Banjarmasin), West Nusa Tenggara and East Nusa Tenggara.

Finding out someone's health status in the past can be achieved by examining skeletons that can be used to reconstruct ancient human life (Jacob 1972, 1977; Bosch 2000; Suriyanto 2020). For instance, changes in diet can lead to various diseases because diet is recorded on masticatory organs, such as teeth (Steckel and Rose 2002; Steckel 2005; Suriyanto 2020). Teeth and mouth are organs that also served as social organs in the past. In the ancient period, human social status was indicated by teeth modification and the use of dental accessories, such as ablation, staining, and the addition of non-biological materials such as rocks are examples of such modifications (Suriyanto and Koesbardiati 2010; Koesbardiati et al. 2015, 2018; Koesbardiati and Murti 2019).

The disease can also be triggered by contact with other populations (Larsen

et al. 2007; Suriyanto 2020). These diseases spread from local to regional areas and can sometimes turn into epidemics, such as plague. The practice of colonization had facilitated outbreaks of many diseases and, arguably, gave origin to various epidemics, such as avian influenza, swine flu, plague, and smallpox. The easier and faster mobility coupled with an easy access to transportation, the faster and the wider the spread of diseases from one area to another. Ancient people recorded the experienced by them life events in various cultural artifacts (Buzon et al. 2005; Suriyanto 2020). Some notable events related to diseases, such as outbreaks, epidemics, or pandemics, also attracted their attention, which is recorded in rock drawings, pottery, reliefs, and inscriptions. This information can not only provide a better understanding of diseases in the past but also can help in dealing with similar diseases in the future (Bosch 2000; Suriyanto 2020).

The Gilimanuk site (2000 BP) is located by the side of the beach. Gilimanuk used to be once a coral reef ocean area. It was surrounded by water during the Pliocene era but now is a part of the mainland. The combination of land and calm waters calms the east side of Gilimanuk, accumulating fine sediment. This sediment then serves as a habitat for the development of mangrove forests (Soenarto 1993). Mangrove forests provide a safe habitat for fish and other animals. There is enough fresh water in the surrounding environment to support life. People at the time were most likely able to make a living as fishermen thanks to their easy access to the sea (Aziz 1995). This community consumed marine animals and land animals as evidenced by the discovery of the remains of bones

and teeth of pigs and chickens (Soejono 1977). The first study published in 1962 revealed human skeletons and pottery. Based on these findings, further research was carried out from 1963 to 1977 with a total of 40 sectors and the opening of 37 excavation boxes (Soejono 1977). The human skeletons in Gilimanuk which are stored at the Bioanthropology and Paleoanthropology Laboratory come from excavations from 1964 to 1977.

The Semawang site is located on Sanur Beach, in the South Denpasar District of Badung Regency, Bali Province, Indonesia. At the Semawang Site, the soil is composed of loose sand, sandstone, shells, and coral fragments (Harkantiningih 1990). It was first discovered by a resident upon whose report a research survey was conducted followed by three excavation phases in 1986, 1988, and 1990. Frames I–III were unearthed in 1986, frames IV–VIII in 1988, and frames IX–XV in 1990. The human skeletons were excavated in 1986–1988 at the Semawang site. Grave goods found at the site included animal skeletons, kereweng (a type of Balinese gamelan instrument), metal objects, shells, and beads (Yuliati 1990). The fauna of the area includes monkeys, starlings, pangolins, porcupines, pigs, monitor lizards, turtles, dogs, and snakes. Meanwhile, mangroves, coconuts, ketapang, and camplung are common coastal plants, and many rice fields are planted with rice, secondary crops, and lowland horticulture (Gautama 2011).

Nestled on the northern coast of Bali, Pacung Sembiran stands as twin sentinels of a rich maritime heritage. Situated within the Tejakula District of Buleleng Regency, this site occupies a strategic position, marked by their precise coordinates of 8°31'45" East Longi-

tude and 8°7'32" South Latitude. Poised at an elevation of 25 meters above sea level, Pacung Sembiran unfurls along a 700-meter stretch, 250 meters from the coastline. The strategic location has long captivated traders from distant lands, making it a bustling hub of maritime commerce for over two millennia. Archaeological investigations at the Pacung Sembiran sites commenced in 1987 and continued with multiple excavation seasons until 2008, with a resumption in 2012. These endeavours yielded a remarkable abundance of artifacts, including Indian pottery, pig's teeth, and bronze tools crafted in Pacung Sembiran. This rich archaeological record points to the existence of thriving communities in Pacung Sembiran dating back to at least the first century AD, corresponding to Bali's paleometallic or iron-bronze period (Ardika et al. 1997; Calo et al. 2015). Fresh water is only available in areas near the beach. The human skeletons were excavated in 2004–2005 at the Pacung Sembiran site. The drying of the land means that people must work as fishermen, traders, or gardeners. This location has been occupied by humans for an estimated 2200 years. Pacung Sembiran has a calm coastline and a deep bay, making it easier for ships to anchor (Ardika 1991; Suastika 2008).

Drawing upon the rich archaeological record of Bali's past, this study seeks to elucidate the types and prevalence of diseases that afflicted ancient populations in Gilimanuk, Semawang, and Pacung Sembiran. By delving into the paleopathological landscape of these communities, this study can provide a better understanding of diseases in the past so that it can be useful for dealing with these diseases in the future.

Materials and Methods

Sample

This study examines the morphology of the human skeletons derived from three locations in Bali, Indonesia: Gilimanuk (114°26′–114°56′30″ E and 80°5′20″ S), Semawang (111°35′04″ E, 6°3′33″ S), and Pacung Sembiran (8°27′12″ E, 8°42′19″ S), collected between 1964 and 2008 (Fig. 1). The human skeletons were obtained from the Gilimanuk (300 individuals) site, the Semawang (11 individuals) site, and the Pacung Sembiran (25 individuals) site. To reconstruct the health condition of the representatives of the examined past populations from these sites, a paleopathological approach (Rühli et al. 2016) was used through macroscopic observations of the undamaged remains of the bones and teeth. Data were collected in December

2023. This study has been approved by the Medical and Health Research Ethics Committee, Faculty of Medicine, Public Health, and Nursing Universitas Gadjah Mada (No. KE/FK/1913/EC/2023).

Procedure

The first stage of the study included making macroscopic observations of the skeleton to determine the availability of the skeleton as a sample. In the next stage, the surface of the bones was cleaned from dust and sand to enable observations on the surface of the bones. The following stage involved sex identification by looking at the sex markers (nuchal crest, mastoid process, supraorbital margin, glabella, mental eminence) on the skull bone (Buikstra and Ubelaker 1994). If no sex markers were found, sex was categorized as unidentified.

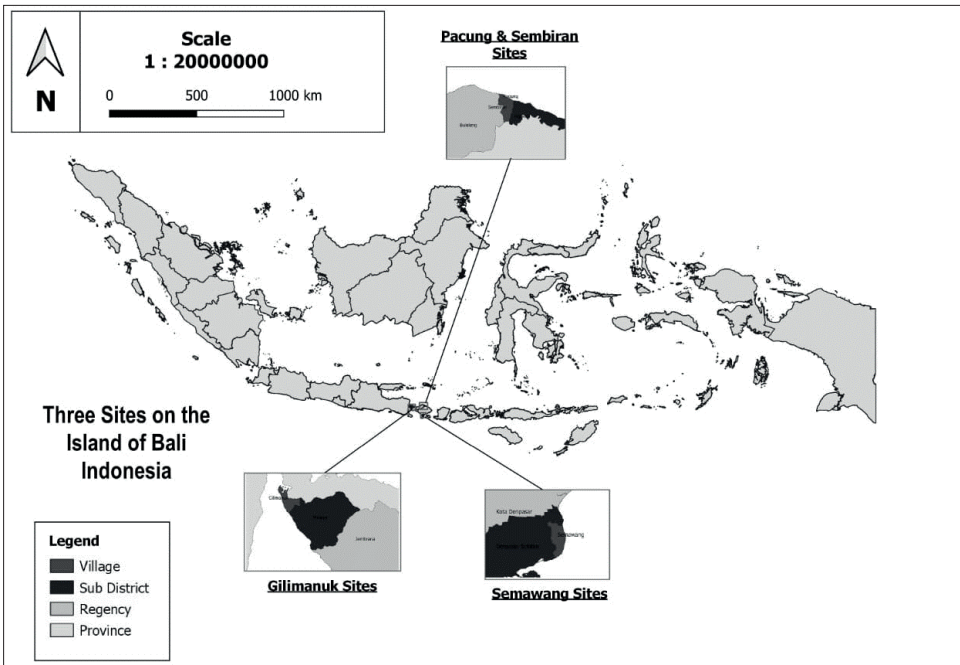


Fig. 1. Location map of Gilimanuk, Semawang, and Pacung Sembiran sites, Bali Indonesia

The method used in this study for detecting pathological changes in skeletal remains involved meticulously examining individual bones and teeth. Each specimen was scrutinized, and, to minimize the risk of misdiagnosis, the bones or teeth were compared to healthy specimens. The next stage consisted of determining the age at death by assessing the auricular surface, pubic symphysis, or the sutures of the skull and teeth. Age at death was determined by examining the closure of the cranial sutures (Buikstra and Ubelaker 1994), and severe attrition (Lovejoy 1985). Subsequently, disease on the surface of bones and teeth was identified (Aufderheide et al. 1998; Ortner 2003; Roberts and Manchester 2005). Assessment of the diseases was conducted as follows: caries (Lukacs 1989), Enamel hypoplasia (Hillson 1997), periodontitis (Lukacs 1989), severe attrition (Lovejoy 1985), calculus (Brothwell 1981), osteophytes (Jurmain 1990), porotic hyperostosis (Stuart-Macadam 1985), and spina bifida occulta (Aufderheide and Rodríguez-Martín 1998). During the final stage of the study an analysis of the results of observations to determine the type of disease and disorder was conducted.

Results

Descriptive statistics on the subjects and types of pathological changes at the Gilimanuk, Semawang, and Pucang Sembiran sites are listed in Table 1. Figures 2–4 show dental caries and calculus, and osteophytes on lumbar vertebra of the individual derived from the Gilimanuk site. Figure 5 shows the pangur on the incisor teeth from the Pacung Sembiran site.

The Gilimanuk site (2000 BP) used to be a community group residing on the

beach. This study examined 300 Gilimanuk skeletons consisting of 50 adult males, 63 females, 135 children, and 52 sex-unidentified adults. The age range for adults was between 16 and 60 years, and for children between 0–15 years. Most of the skeletons were in a fragmentary state. The identified pathological changes in this population were trauma-related, such as fractures or myositis ossificans, degenerative diseases, such as osteoarthritis, infections, and congenital abnormalities such as closed ear canals. Dental diseases, such as caries, periodontal disease (periodontitis), enamel hypoplasia, or traces of consumption of areca were also common. In addition, severe attrition and calculus were found in the ancient Gilimanuk community (Tab. 1).

The Semawang population on Bali's Sanur Beach lived in a similar location to the community of Gilimanuk site, with relatively the same culture during the Paleometallic period around 2000 BP (Yuliati 1990). The skeleton population from Semawang consisted of 11 individuals (five males, five females, and one child aged around 10 years). The age range was 25–40 and 20–40 years for males and females respectively. There was no visible disease in the children. In contrast, the adult individuals showed caries, enamel hypoplasia, and changes caused by periodontitis (Tab. 1), similar to the ancient Gilimanuk people. The ancient Semawang people were also found to have severe attrition and calculus on their teeth. Some individuals demonstrated visible teeth modification locally known as pangur (teeth filling) and traces of betel nut consumption. One individual (female) showed an abscess on the mandibular first molar, possibly indicating that the periodontal disease has reached a severe level (Ortner 2003).

Table 1. Paleopathological types of skeletons of ancient populations in Gilimanuk, Semawang, and Pacung Sembiran, Bali Indonesia

Population	Skeleton	Paleopathological lesions	Sex				Number of individuals
			M	F	UN		
					A	NA	
Gilimanuk (300)	Teeth	Caries	–	4	–	1	5
		Enamel hypoplasia	5	6	–	–	11
		Periodontitis	1	1	–	–	2
		Abscess	–	1	–	–	1
		Severe attrition	6	10	1	5	22
		Calculus	13	17	–	–	30
	Bones	Osteophytes	10	10	2	–	22
		Fracture	5	3	–	1	9
		Porotic hyperostosis	4	1	–	–	5
		Spina Bifida Occulta	2	2	–	–	4
Semawang (11)	Teeth	Caries	2	1	–	–	3
		Enamel hypoplasia	1	–	–	–	1
		Periodontitis	2	2	–	–	4
		Abscess	–	1	–	–	1
		Severe attrition	3	2	–	–	5
		Calculus	3	2	–	–	5
	Bones	Osteophytes	–	–	–	–	–
		Fracture	–	–	–	–	–
		Porotic hyperostosis	1	–	–	–	1
Pacung Sembiran (25)	Teeth	Caries	2	–	3	1	6
		Enamel hypoplasia	1	1	–	1	3
		Periodontitis	–	–	–	–	–
		Severe attrition	2	1	3	–	6
		Calculus	2	4	4	1	11
	Bones	Osteophytes	–	–	–	–	–
		Fracture	1	–	1	–	2
		Porotic hyperostosis	2	–	–	–	2

M: male; F: female; UN: unknown; A: adult; NA: non-adult

Situated on the northern coast of Bali, the Pacung Sambiran sites lie 250 meters above sea level. The Pacung Sembiran people, who inhabited Bali during the early first century AD, lived during the Paleometallic or iron bronze period (Calo

et al. 2015). A total of 25 skeletons were examined, comprising 8 adult males, 7 adult females, and 6 children while sex of 4 adult individuals could not be determined. The age range spanned from 16 to 45 years for adults, and 8 to 10 years

for children. Various pathological changes were identified among these individuals, including enamel hypoplasia, caries, porotic hyperostosis, and fractures (Tab. 1). Additionally, a supratrochlear foramen was found on the humerus. There were also a lot of severe attrition and dental calculus observed in individuals from the three above-mentioned sites which could be considered as a degenerative or physiological change rather than a disease.

Discussion

The majority of pathological changes identified in human skeletal remains obtained from Indonesian sites typically manifest in the teeth. This is primarily due to the teeth's exceptional durability, making them the most resilient part of the body, capable of preserving evidence of pathological changes long after other tissues have decomposed (Roberts and Manchester 2005). Furthermore, teeth serve as the initial point of entry for food, increasing their susceptibility to the accumulation of various pathogenic agents (Ungar 2014). Among dental diseases, caries, enamel hypoplasia, and periodontitis are the most prevalent findings.

Dental caries, a prevalent disease in modern society, serves as a mirror reflecting an individual's oral health and dietary habits. This infectious disease of the teeth, caused by the activity of bacteria like *Streptococcus mutans* and *Lactobacillus acidophilus* (Roberts and Manchester 2005), typically damages the tooth's structure, crown, or roots, potentially disrupting mastication processes and diminishing overall quality of life (Sheiham 2006). The presence of dental caries in all three populations examined at this research site, both in

the maxilla and mandible teeth, can be attributed to dietary shifts from hunting to agriculture, leading to increased consumption of carbohydrates and vegetable protein, consequently fostering the development of caries (Klaus 2017). The high frequency of caries alongside tooth loss may also indicate underlying health issues, particularly those related to dietary habits (Ungar 2014). This study found that females have a higher prevalence of caries compared to males, which is supported by Boonlop (2018), who studied 362 prehistoric human skeletons (5000 BP) from 13 archaeological sites in Thailand and discovered that females were more likely than males to have dental caries. Dental caries disease was found in 3 out of 11 individuals from the Semawang site, in 5 out of 25 individuals from the Pacung Sembiran site, and in 5 out of 300 people from the Gilimanuk site (Tab. 1), where many female individuals were affected by this disease (Fig. 2).



Fig. 2. Dental caries on maxillary premolar and molar at the Gilimanuk site (individual IA)

Enamel hypoplasia (EH) is a dental condition characterized by defects in the enamel, manifested as lines, small holes, or indentations (Roberts and Manchester 2005). It can be associated with various diseases, including syphilis, rickets, dental trauma, tuberculosis, and malnutrition (Ortner 2003). Although EH is not as prevalent as severe attrition, calculus, or caries, it was observed in specimens derived from these three sites. In the Pacung Sembiran populations, around 3 out of 25 individuals exhibited EH, while in the Semawang population, 1 out of 11 individuals were affected. In contrast, only around 11 out of 300 individuals of the Gilimanuk people experience this condition (Tab. 1). Several factors contribute to EH, including trauma, metabolic stress, genetics, and environmental pressures. Research by Koesbardiati et al. (2018) on ancient populations revealed the presence of EH in 14% (7 individuals) of individuals from the Liang Bua site and 16% (3 individuals) from the Melolo site in East Nusa Tenggara, Indonesia. Noerwidi (2020) study of the Javanese Binangun and Leran populations, residing on Java's north coast, indicated that 5 out of 10 individuals (50%) experienced EH. These findings suggest that life on Java's north coast may have been challenging in the past, exposing the population to many pressures. King et al. (2005) highlighted the potential of using EH as an indicator of assessing childhood growth and patterns of morbidity and mortality in past populations. However, only one child found in the Pacung Sembiran sites exhibited EH. Klaus (2020) proposed that the frequency of enamel hypoplasia in a population tends to increase with the intensification of agricultural practices, population growth, and rising social complexity.

Concurrent with enamel hypoplasia, periodontitis was also observed in the studied populations. Periodontitis, also known as gum infection, is a destructive that affects soft tissues, supporting bone structures, and can also affect teeth. It arises as a complication of untreated gingivitis, an inflammation of the gums. Periodontitis has been documented since 130 years ago in Neanderthal Kaprina, Croatia (Murti et al. 2023). The incidence of periodontitis in the sample of the individuals from the Gilimanuk site was lower compared to other dental diseases, found in only two individuals (one male and one female) from the Gilimanuk site, while there were four individuals (one man and three women) at the Semawang site were affected, whereas no cases were found at the Pacung Sembiran site (Tab. 1). Research conducted by Murti et al. (2023) on a skeletal population from Kotabaru, South Kalimantan, Indonesia, revealed the presence of periodontitis affecting the maxillary anterior teeth, attributed to a high-carbohydrate plant-based diet.

Betel nuts are commonly consumed in Asia and the Pacific. Betel nut leaves reddish-brown stains on the teeth (Koesbardiati and Murti 2019). Betel nut chewing has also been proposed as a potential contributing factor to periodontitis, with its ingredients potentially triggering inflammation in the periodontal tissues. In addition, oral health status and vitamin C deficiency may play a role in the development of this disease (Noerwidi 2020). According to archaeobotanical reports, areca pulp (*Areca catechu* L) can chew betel (Zumbroich 2007/2008). Meanwhile, Rusyad and Koesbardiati (2010) discovered tooth coloring in Polynesia and Micronesia, using lime, areca nut (*Areca catechu*), gambier (*Uncaria*

gambir Roxburgh), and betel (*Piper betel*). Nguyen (1990) described the widespread practice of applying black varnish to teeth in Vietnam and its impact on the incidence of dental caries, whereas Suddhasthira et al. (2006) reported that this habit is commonly practiced by Thai people and, according to archaeological remains, this tradition was carried out around 5000–4000 years ago.

Apart from the three diseases described above, many individuals from the above-mentioned sites were found with calculus and severe attrition. Tooth attrition involves a gradual loss of tooth structure or tissue due to contact between teeth. This erosion of the tooth layer occurs over time as a result of excessive friction between the upper and lower teeth during chewing (Sperber et al. 2017). In ancient societies, severe tooth attrition was often observed due to dietary habits and rudimentary food processing techniques. Heavy diet patterns, such as the consumption of abrasive materials mixed with food, coupled with limited use of fire to soften food, contributed to the high prevalence of tooth wear in these populations (Roberts and Manchester 2005). In the Semawang population, 5 out of 11 individuals showed signs of tooth wear, while in the Pacung Sembiran population, 6 out of 25 individuals exhibited signs of tooth wear. In contrast, the residents of Gilimanuk showed incidents of tooth wear in 22 out of 300 individuals. As noted by Sperber et al. (2017), wear patterns on teeth can provide valuable insight into the properties of food materials consumed by a population. It might be that severe attrition observed in this ancient human populations residing in coastal habitats was primarily caused by the ingestion of sand particles carried by

soft-bodied organisms, such as shellfish or snails, which were likely part of their diet. As suggested by Noerwidi (2020), ancient people in Binangun and Leran sites, North of Central Java consumed snails as a part of their diet.

Dental calculus, also known as tartar, is a hardened form of dental plaque, a sticky film of bacteria that adheres to the surface of teeth. This calcification occurs when minerals from saliva and gingival crevicular fluid interact with plaque, leading to the formation of a hard, crusty deposit. The presence of tartar on the teeth of individuals who lived millennia ago offers a valuable insight into their dietary habits, types of bacteria that inhabited their oral cavities, and their overall oral health (Roberts and Manchester 2005). Among the dental changes identified, calculus exhibited the highest prevalence in the Pacung Sembiran sites compared to the Gilimanuk and Semawang sites. For example, 5 out of 11 individuals from the Semawang site exhibited calculus, while in Pacung and Sembiran 11 out of 25 individuals showed calculus (Tab. 1). In the Gilimanuk population, the incidence of calculus accounted for 30 out of 300 individuals. The formation of calculus is linked to the accumulation of food debris between teeth that remain uncleaned (Fig. 3). A high prevalence of calculus is typically associated with high consumption of carbohydrates and proteins or an environment with acidic water (Roberts and Manchester 2005). Noerwidi (2020) posited a link between calculus formation and the consumption of sugary foods or beverages. Research by Prayudi and Suriyanto (2018) revealed the presence of calculus and periodontal disease, in individuals from the Paleometallic period.



Fig. 3. Dental calculus on the maxillary premolar and molars at the Gilimanuk site (individual IA)

In addition to the periodontal disease mentioned earlier, other prevalent bone pathological changes included osteophytes, fractures, porotic hyperostosis, and spina bifida occulta. Osteophyte disease manifests itself as a form of the body's reaction to disorders surrounding the joints. Variations in age, sex, population, and mechanical stress are known to influence bone osteophyte changes. The incidence of osteophytes in ancient populations was not observed at the Semawang and Pacung Sembiran sites, whereas at the Gilimanuk site approximately 22 out of 300 individuals exhibited signs of osteophytes (Fig. 4). Our data suggest that the incidence of osteophytes at the Gilimanuk site does not differ between males (10 individuals) and females (10 individuals), while 2 cases of osteophytes were detected in children. This is not in line with the Kim et al. (2012) study that stated that more severe osteophytes occur more often in men be-

cause, compared to women, they tend to perform heavier physical activity. In this study, osteophytes were frequently found on the vertebrae and metatarsals.



Fig. 4. Osteophytes on a lumbar vertebra at the Gilimanuk site (individual VIII)

Fractures, a common bone disease in humans that have been present throughout history, were also observed in the Gilimanuk, Pacung, and Sembiran populations. Fractures were found in nine out of 300 individuals at the Gilimanuk site and two out of 25 individuals at the Pacung Sembiran site, with a higher frequency in males. This trend is consistent with the findings of Domett and Tayles (2006), who studied the skeletons of the adult Thai population (2000–400 BC) and reported that the number of male sufferers (12 individuals) was higher than that of females (7 individuals). These individuals' fractures are most likely the result of a combination of everyday accidents, such as agriculture and animal husbandry, as evidenced by fractures in long bones. Moreover, fractures in the skull might indicate interpersonal

violence. Fractures in the Gilimanuk population were primarily found in the rib bones, while fractures in the Pacung Sembiran sites were more common in molar teeth, which are fractures of the tooth crown that occur while the individual is still alive. Further examination revealed that all fractures in the costal bones had healed, as evidenced by the presence of bones that had reconnected but were not evenly connected, which suggests a natural healing process.

Porotic hyperostosis is exhibited by small, pore-like holes typically found on the frontal or parietal bones of the skull, with a few occasionally present on the occipital bone. These holes are usually symmetrical and, in advanced stages, may give the impression of skull thickening. According to Aufderheide et al. (1998), these holes are indicative of anemia but can also arise from other diseases such as leukemia, thalassemia, aplastic anemia, or potential malnutrition. Blom et al. (2005) observed a higher prevalence of porotic hyperostosis in coastal populations compared to those residing in highlands. The incidence of porotic hyperostosis at the Semawang site was 1 out of 11 individuals, at Pacung Sembiran 2 out of 25 individuals, while at the Gilimanuk site, 5 out of 300 individuals exhibited porotic hyperostosis (Tab. 1). Notably, the parietal bones were the most commonly affected by porotic hyperostosis. Associated with porotic hyperostosis is cribra orbitalia, which was also found in one juvenile at the Gilimanuk site. Cribra orbitalia was not observed in individuals from (Semawang and Pacung Sembiran). Klaus (2020) posits that porotic hyperostosis and cribra orbitalia have long been associated with metabolic disorders linked to anemia. Cribra orbitalia and porotic hyperostosis

are morphological syndromes that can be manifested as downstream consequences of various secondary conditions associated with chronic anemia. Walker et al. (2009) also highlight that porotic hyperostosis and cribra orbitalia are among the most frequently observed pathological lesions in ancient human skeletal assemblages. Since the 1950s, chronic iron deficiency anemia has been widely accepted as a plausible cause of both conditions.

Spina bifida occulta (SBO) is a spinal disorder that often associated with chronic back pain. According to the Spina Bifida Association (Aufderheide et al. 1998), approximately 10–20 percent of individuals are affected by SBO. What makes SBO unique is that many individuals who have this condition are unaware of its presence, as symptoms may be absent. SBO can occur along any part of the spine but is most prevalent in the sacral region (Aufderheide et al. 1998; Merbs 2004), and, in this instance, it is referred to as sacral spina bifida occulta (SSBO). In this study, SBO was only observed at the Gilimanuk site, affecting four adult individuals (two males and two females). Research by Molto et al. (2019) on a skeletal population inhabiting the Dakhleh Oasis, Egypt, reported that around 15.6% of the sample exhibited SSBO, with a temporal increase in males. In addition, in both sexes SSBO tended to increase with advancing age. All of the four individuals with SBO at the Gilimanuk site were found in the sacrum bone. The age range for the male individuals was between 20 and 40 years, while the female individuals were between 25 and 30 years old.

In addition to the above-mentioned bone and dentition diseases, evidence of dental modifications, such as *pangur* is (tooth-filing) and betel chewing, has

been unearthed at these archaeological sites. As noted by Noerwidi (2020), the examination of cultural practices on human skeletal remains provides valuable insights into living habits and cultural identity in the past, often manifested in the form of morphological alterations to specific body parts, such as teeth. Dental modifications in the forms of *pangur* and betel chewing have been observed at the Gilimanuk, Semawang, and Pacung Sembiran sites. At the Pacung Sembiran site, there were around 12 out of 25 individuals exhibiting signs of betel chewing, as evidenced by tooth discoloration. At the Gilimanuk site, 17 individuals engaged in betel chewing practices, while approximately 22 individuals displayed *pangur* tooth modifications. Among the population at the Semawang site, six individuals exhibited tooth filling, but no evidence of betel chewing was found. *Pangur* typically involves filing the visible portions of the teeth from the outside of the mouth. This practice persists in several regions of Indonesia, including Bali, and may serve as a marker of gender distinction post-puberty (Prayudi et al. 2020). The majority of tooth modifications observed at the three aforementioned sites are located on the maxillary and mandibular incisors. Noerwidi (2020) study on ancient populations at the Binangun and Leran sites on the North Coast of Java reported evidence of betel chewing practices, with remnants of areca nut and chalk observed on the buccal and lingual surfaces of several molar teeth.

This study offers valuable insight into the types of pathological changes and health conditions that prevailed among ancient populations of Gilimanuk, Semawang, and Pacung Sembiran, situated in coastal regions on the island of Bali. Several dental diseases predom-

inated in these populations. This study, however, has its limitations and requires further refinement. More research, incorporating microscopic observations and molecular approaches, is needed to gain a more comprehensive understanding of the specific diseases and infections that afflicted the ancient inhabitants of these sites. The outcomes of this research will contribute to addressing contemporary health challenges and inform preventive measures.



Fig. 5. *Pangur* on maxilla teeth at the Semawang site (individual XII)

The results of the identification of 336 skeletons of ancient populations from the Gilimanuk, Semawang, and Pacung Sembiran sites on the Indonesian island of Bali show the dominance of caries and enamel hypoplasia. Bone diseases and abnormalities that can be observed include osteophytes, porotic hyperostosis, fractures, and spina bifida occulta. Moreover, there are traces of betel nut consumption and tooth modification in the form of *pangur* (teeth filing) in some individuals.

The presence of disease in ancient humans at these sites indicates similar types of disease with unequal prevalence. However, the absence of disease markers in certain individuals doesn't necessar-

ily imply they were healthy during their lifetime. Alternative possibilities include diseases that didn't leave skeletal traces, such as skin diseases, or the individual's death before the disease manifested in skeletal lesions.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication.

Authors' contributions

NTR – was the lead researcher, conceived the concept and design, identified samples, data collection, article writing, and critical revision of the article for important intellectual content; AP – identified samples, performed data collection, and critical revision of the article for important intellectual content; RAS – identified samples, performed data collection and compilation; JH – performed data collection and compilation; FA – performed data collection and the photographer; ARH – performed data collection. All authors discussed the results and contributed to the final manuscript for publication.

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