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Human dental wear on the Late Holocene population, Papua-Indonesia*

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Abstract

This study aims to find out the wear pattern and the explanations behind tooth wear in the Late Holocene population in the lowland part of Papua. For this, 51 permanent teeth from five different archaeological sites were investigated to find out the wear patterns of these teeth. In this study, wear patterns in incisors, canines, and premolars were described using the medium-resolution microscope Novex Holland. In addition, the wear and mechanical processes on the occlusal molars during the chewing cycle were interpreted. The results show that types of wear such as attrition, abrasion, erosion, and fracture are present in the incisors, canines and premolars which may be caused by the different types of food consumption. The chewing cycle method presents the wear frequencies, which vary between the sites. The teeth from Yomokho, Srobu, and Mamorikotey showed a highest impact of wear in the buccal phase I that may cause by the tough types of food consumption that require a high'shearing' process. While the teeth from Namatota and Karas sites present the highest wear in phases lingual I and II, which could be attributed to the abrasive and rougher type of food texture, the process involves power strokes of crushing and grinding.

Keywords: tooth wear; abrasion; attrition; erosion

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Introduction

Human teeth are part of a larger field of study that encompasses dentistry, biological anthropology, biarchaeology, dental anthropology, and a variety of other disciplines (1, 2, 3). Human dental wear is characterized by the loss of dental hard tissue associated with tough-fibrous and coarseness of the diets and masticatory activity on the teeth crown area (4, 5, 6, 7). Tooth wear refers to the loss of dental hard tissues caused by environmental, chemical, and mechanical processes of everyday use, including food mastication (8, 9). In the archaeological study, the teeth wear has long been considered impacted by human behaviour, presents evidence about diet preferences and masticatory mechanism (10, 11). In clinical terms, abrasion refers to wear caused by foreign bodies such as tools or coarse food, whereas erosion denotes to chemical demineralization of tooth tissue that does not include bacterial (8). In addition, attrition is one of wear process developed caused during the tooth grinding or mechanical tooth wear (12). Insights into past human information, behaviours may provide knowledge on an important and ongoing debate concerning human evolution. In addition, the examination of tooth wear might provide a hint of the diet compositions and food preparation methods, which have a direct connection to daily human life. However, the lack of study about human teeth wear especially from the prehistoric people have limited the understanding about the human past behaviour. Furthermore, this research is based on the premise that tooth wear patterns can provide information about past human dietary behaviour than can be seen by microwear on the tooth crowns of anterior and posterior teeth from in this study.

The purpose of this study is to record and understand the dental wear patterns in human dentitions from five archaeological sites in the lowland part of Indonesian-Papua. The archaeological sites concerned are Mamorikotey, and Srobu are located on the Cenderawasih Bay in the northern coast of Papua, while two sites, Karas and Namatota located in the south coast of Papua (Figure 1).

Materials

51 teeth from 45 individuals were collected through excavation in 5 different archaeological site, including Mamorikotey, Srobu, Karas, Yomokho and Namatota in Province of Papua, Indonesia. The Srobu site is located in Youtefa Bay, Jayapura-Papua Province (S 2.617937º E 140.703464º). The location spans around 20,059 m2 of the peninsula, is located at a height of roughly 85m. Several square meters of boxes were opened systematically as part of the excavation process. The archaeological findings such as human remains, including teeth were discovered in this site. Some of the teeth were found together with skulls, whereas several of them were encountered from the fragile-jaw. Several human skeletons were unearthed within pottery jars that also included glass bead, jewellery and animal teeth (13). The earliest dates that can be determined by radiocarbon at these sites is 1720-30 BP (14); however, this date come from a charcoal sample taken from a different unit, not the unit B2S1 where the human remains used in this study. Thirty individuals' teeth (Figure 2) were applied in this study from the Srobu site (Table 1).

Mamorikotey is an open site on Kapotar Island in Nabire Regency-Papua (S.30736670; E 135.5902780). It is located on a hill 75 metres above sea level (asl) and 20-30 metres from the shoreline. Three square-metre excavation boxes were opened on the site: MMK1, MMK2, and MMK3, and excavated with 10 cm spits. The charcoal sample analysis from MMK3 at a depth of 115 cm resulted the dated 2520±50 BP (IHME-3995). This study employed 5 posterior teeth and 3 anterior teeth from the Mamorikotey site, including Mmk/42 with an upper first premolar (UP1) tooth and Mmk/49 with a lower canine (LC). The individual Mmk/78 has an upper first incisor (UI1), while Mmk/79 with upper second incisor (UI2) and Mmk/332 with lower second premolars (LP2). Mmk/333 with lower first premolar (LP1), Mmk/405 and Mmk/640 with lower first premolar (LP1) (Figure 2).

Namatota is an open archaeological site, located in the Namatota district, in Kaimana Regency of Papua Barat Province; it positioned: S 3.313768º; E 132.669722º. One square meter test pit was opened at this site, where archaeological material was recovered from 1 to 100 cm from the string level. 2 individuals from Namatota site including NMT1 and NMT2 were recovered during the excavation in this site. NMT1 has two teeth: lower premolar 1 and lower premolar 2. NMT2 has four teeth: the lower first incisor (LI1), the lower second incisor (LI2), the lower first premolar (LP1), and the lower second premolar (LP2) (Figure 2). The radiocarbon dating of a charcoal sample was taken at a depth of 76 cm yielded a date of 11040 BP (IHME-3994).

Karas is a cave site situated in Arguni District in the Kaimana Regency, Papua Barat Province, Indonesia (S 3.306583º; E 133.750556°). The site is located on a hill in the Arguni Bay area, about 45 metres above sea level. The archaeological research at this site was conducted through excavation in three boxes, namely GKQ1 (I6), GKQI (F5), and GKQ1 (F6), all of which were located in the same sector. The human teeth remains in this study were encountered in GKQ1 (F6) including: Krs/41, with lower canine (LC), Krs 334, with lower premolar 1 (LP1), Krs/638 with upper canine (UC), and krs/649 with upper second premolar (UP2) (Figure 2).

Yomokho is an open archaeological site, situated on a hill on the north shore of Lake Sentani in Jayapura Regency (S 2.590125º; E 140.610278º). The Yomokho site yielded two human mandible jaws. The lower left jaw was discovered on the cliffs of the Yomokho site, with half of it partially buried in the hill walls. There are two teeth available in this jaw: the lower left second premolar (LLP2) and the lower left first molar (LLM1). For this site, one radiocarbon determination based on charcoal dating to ≤2590 BP is available (15).

Methods

The teeth wear is known to exhibit different patterns in each individual; the wear rate was measured through the scoring method. The tooth wear is examined through descriptions and detailed photographic documentation using the medium-resolution of the microscope in all teeth by using the stereomicroscope Novex Holland with 25X magnification. The microscope allows identification clearly to identify the microwear such as pits and scratches teeth surface, at the facial, lingual, buccal area of anterior and posterior teeth. The wear traces were examined using a wide range of magnification, ranging from 100 to 250 diameters. The human teeth: incisors, canines, premolars, and molars are subject to dental wear, e.g., attrition, abrasion, and erosion, which variously established in the different angle depend on morphology features in each tooth. The information about teeth wear was recorded, including the intensity, frequency, and the size of the tooth wear, to provide information about the human's diet behavior in this research. Thus, the scoring method provided by Smith's (1984) (6), and Brothwell's (1981) (5) are applicable to use to these four teeth types; it has been used widely by researchers from different field including archaeologist to study the human teeth wear found in the archaeological site (3), (5), (6), (16) were proposed the scoring system to estimate the wear in incisors, canines, and premolars teeth. Smith's (1984) scoring system is used to identify the wear on the incisors, canines, and premolars teeth as will explained as follows:

Incisors and Canines:

1. Unworn to polished or small facets (no dentin exposure)
2. Point or hairline of dentin exposure
3. Dentin line of distinct thickness
4. Moderate dentin exposure no longer resembling a line
5. Large dentin area w/enamel ring complete
6. Large dentin is w/enamel ring lost on one side or very thin enamel only
7. Enamel rim lost on two sides, or small remnants of enamel remain.
8. Complete loss of crown, no enamel remaining; crown surface takes on the shape of roots

Premolars:

1. Unworn to polished or small facets (no dentin exposure)
2. Moderate cusp removal (blunting)
3. Full cusp removal and/or moderate dentin patches
4. At least one large dentin exposure on one cusp
5. Two large dentin area (maybe slight coalescence)
6. Dentinal areas coalesced, enamel rim still complete
7. Full dentin exposure, loss of rim on at least one side
8. Severe loss of crown height; crown surface takes on the shape of roots

To determine how wear patterns are recreated and what movements are responsible for the contacts on the occlusal part of molar tooth, the movements between lower and upper jaws will be reconstruct to determine the relationship between tooth wear and diet. The chewing cycle method developed by Maier and Schneck, 1981; Kay and Hiiemae, 1974 was applied to obtained information about the possible relative chewing movements at specific part on the occlusal surface and enable the interpretation of the contact areas. Twenty molar teeth (upper and lower) in this study were examined to find out whether the wear was established in buccal phase I, lingual phase I, or phase II (Figure 3).

The correlations between the wear facets area and the type of diet intake are presented in the ternary plots accomplished with the JMP Pro 15 to visualise the links between them. The median, standard deviation, and interquartile range (IQR) of the wear from the five sites were calculated to estimate the average value of wear distributions in Buccal Phase I, Lingual Phase I, and Phase II (Table 2).

Results

Four types of wear were found in the human teeth from five sites in this study: abrasion, attrition, erosion, and fracture (chipped). All macrowear types in the four teeth are characterised by the loss of a portion of the tooth crown as will be described in the following paragraphs:

In the six (6) incisor teeth from Srobu (Srb/64/UI1, Srb/65/UI1, Srb/66/LI2, Srb/67/LI2, Srb/86/UI2, Srb/90/UI2) (Table 1), the wear occurred in the incisal area, as indicated by the loss of enamel area, whereas dentin tissue exposure in the five (5) teeth varied in size. The tooth Srb/86/UI2 presence the abrasion at the enamel area without dentin exposure. However, the fracture in this tooth, as revealed by the fractured and craze-lines at the middle incisal, extended to the cervical third. A fracture or crack from the incisal to the cervical third of tooth enamel indicates incisor wear. The abrasion established the severe conditions indicated by the loss of some part of the crown from the incisal to the cervical third of tooth enamel. Two incisors from Mamorikotey site (MMK/78/UI1 and MMK/79/UI2) presents wear in the form of attrition, abrasion, and cracks displayed in the incisal edges of the two incisor teeth, while in Namatota site, the two lower incisors (NMT/2/LI1 and NMT/2/LI2) exhibited the same type of wear. Except for one tooth, which has lost the enamel and a cusp tip to the middle third area, all the canine teeth from the Srobu site show the same area of tooth abrasion that extends from the cusp tip to the cusp slop. The abrasion displayed in the canines, are considered appeared during the mastication process. The cusp tip is the sharpest part of canines, and it has a specific functions icluding cutting and biting up food. Wear has had an impact on the cusp slop since it is close to the cusp tip and supports it during the food cutting process. The pattern of attrition shown in the incisors from the three sites, including Srobu (Srb/64/UI1, Srb/65/UI1, Srb/66/LI2, Srb/67/LI2, Srb/86/UI2, Srb/90/UI2), Mamorikotey (MMK/78/UI1, MMK/79/UI2), and Namatota (NMT/2/LI1, NMT/2/LI2), presents the parallel scratch marks pattern of attrition in the incisal area. The attrition pattern in these teeth was likely caused by biting foreign substances including food, or by tooth contacts (maxillary and mandibular) during mastication process. Tooth erosion in two Mamorikotey teeth was discovered in MMK/332/LP and MMK/333/LP. The erosion occurred in the anterior and posterior teeth and ranged from minor to severe. The loss of the enamel area roughly 2/3 - 3/4% of the tooth crown implies a moderate rate of erosion, whereas dentin tissue exposure indicates a severe rate of wear as demonstrated by the loss of the enamel that covered the dentin from the tooth crown. In the molar tooth, the erosion is indicated by the flattened or corroded surface present in the occlusal area.

Seven (7) lower molars in the Srobu site are impacted by wear in all sites in buccal phase 1, as evidenced by enamel surface loss, while one tooth (636/LM2), one feature at this buccal phase, is still in good condition while others are affected by wear. Four of the lower molar teeth from the Srobu are fully affected by wear in the buccal phase, lingual phase 1, and phase 2. Except Srb/636/LM2, all areas of wear in the buccal phase area, lingual phase 1, and phase 2 of the seven-tooth lower molars from Srobu are impacted by wear in all chewing spots. In the upper molars, two teeth (Srb/489/ULMI and Srb/ABC/UM1) display mild abrasion in two areas in buccal phase 1, at numbers 1, 2, and 4.

In relation to the statistical comparison result, the explanations of the median, standard deviation, and interquartile range (IQR) statistics (Table 2) are provided in the next paragraph. There is 97% wear in the form of erosion distributed in all chewing areas, buccal phase I, lingual phase I, and Phase II, from the Srobu site, whereas about 3% wear in the form of abrasion is present only in a small area in these chewing phases. In molar teeth from the Namatota site, abrasion appears to be associated with erosion established in buccal phases I and II, while lingual phase I displays no wear. Wear in the form of abrasion was discovered in the Karas site's molar teeth only in the metacone area of the buccal phase I, but no wear was noticed in the lingual phase I or Phase II. In the molar tooth from the Yomokho site, the tooth wear was found to heavily affect the teeth, identified through the loss of half of the tooth crown, from enamel to dentin, in buccal phase I, lingual phase I, and phase II. Wear in the form of abrasion is found in the lingual phase I, at the entoconid location, in the molar teeth from the Mamorikotey site, however there is no wear in the buccal phase areas, I and II.

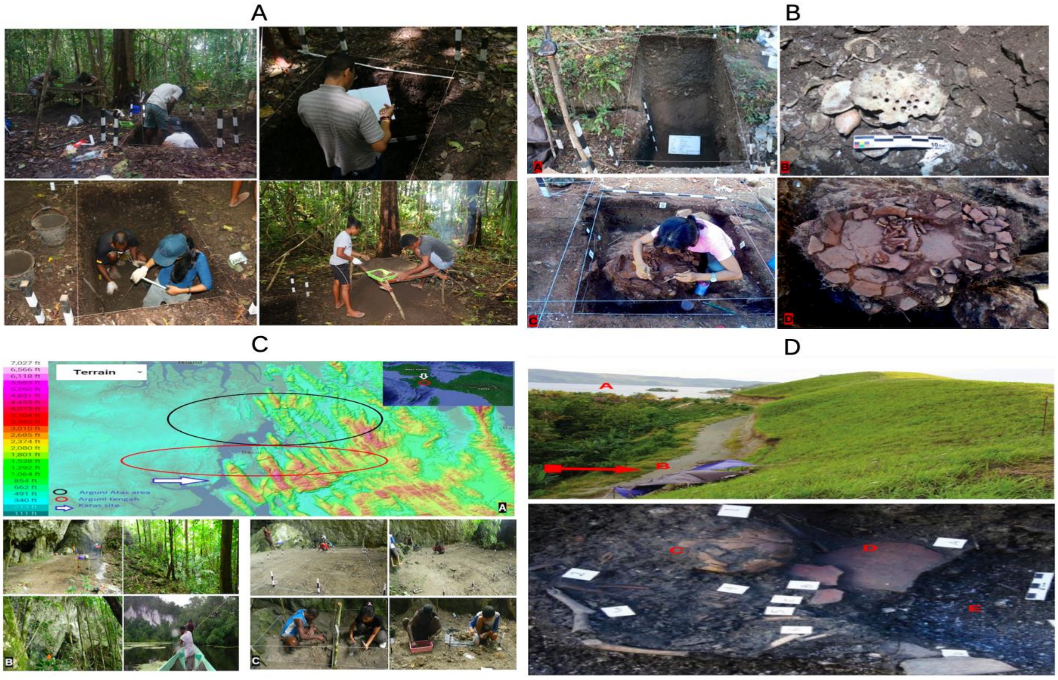

Figure 1. The research activities in archaeological sites in this study. A: Mamorikotey; B: Srobu; C: Karas; D; Yomokho.

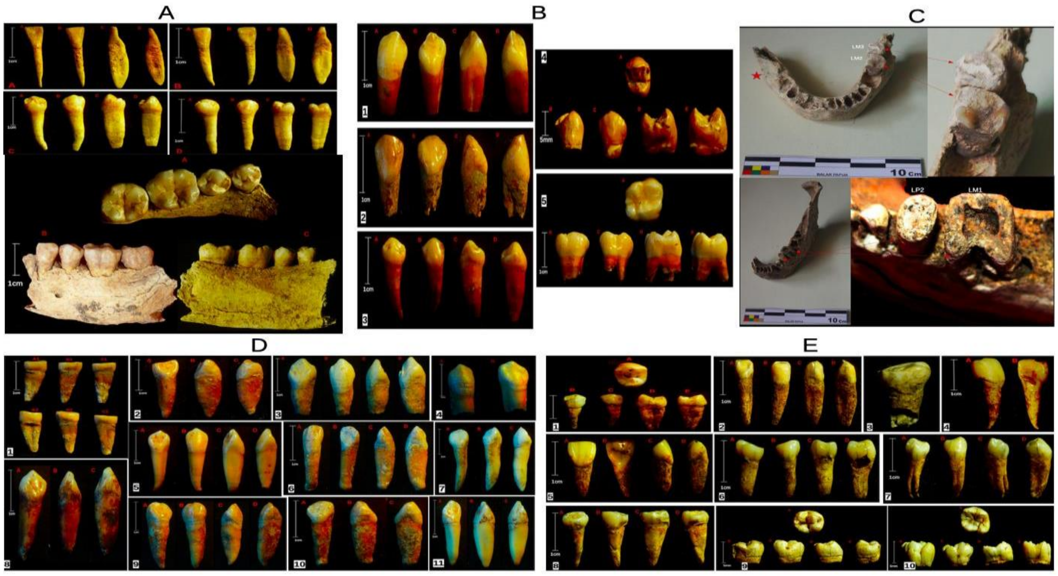

Figure 2. Teeth wear in this study. A: Teeth from Namatota; B: Teeth from Karas; C: Teeth from Yomokho; D: Srobu; E: Mamorikotey.

Table 1. The scoring results of wear and pathology on the teeth from five sites. MMK: Mamorikotey; YMK: Yomokho; Srb: Srobu; Krs: Karas;NMT: Namatota.

Number	Sample Name	Wear I, C, P(range 0-8) B.Holy Smith's (1984)
1	NMT/1/LLP1	1
	NMT/1/LLP2	1
2	NMT/2/LI1	2
	NMT/2/LI2	2
	NMT/2/LP1	1
	NMT/2/LP2	2
3	Krs/41/LC	2
4	Krs/334/LP1	3
5	Krs/649/UC	2
6	Krs/649/UP2	1
7	Ymk/1/LP2	1
8	Ymk/1/LM1	1
	MMK/42/UP1	4
9	MMK/49/LC	5
10	MMK/78/UI1	2
11	MMK/79/UI2	3
12	MMK/332/LP2	2
13	MMK/333/LP1	4
14	MMK/405/LP1	2
15	MMK/640/LP1	7
16	Srb/4/UP1	7
17	Srb/20/LP1	5
18	Srb/20/LP1	5
19	Srb/20/LP2	5
20	Srb/21/UC	1
21	Srb/22/UC	4
22	Srb/23/UC	1
23	Srb/24/UC	2
24	Srb/25/LC	1
25	Srb/27/LC	5
26	Srb/28/UC	2
27	Srb/29/UC	4
28	Srb/30/LC	4
29	Srb/31/UC	5
30	Srb/32/LC	6
31	Srb/33/LC	7
32	Srb/34/IC	6
33	Srb/35/UP1	2
34	Srb/64/UI1	2
35	Srb/65/UI1	2
36	Srb/66/LI2	4
37	Srb/67/LI2	1
38	Srb/86/UI2	5
39	Srb/403/lP2	4
40	Srb/622/LP2	2
41	Srb/623/UC	7
42	Srb/624/LP1	4
	Srb/624/LI2	4
43	Srb/625/LP2	2
44	Srb/626/LP1	2
45	Srb/627/LP1	4

Figure 3. Food processing tools from the lowland archaeological site. Mortars: upper-left and upper-middle. Hammer-stones: upper-right, lower-right. Stone tools: Middle-left and middle-middle; lower-left, and lower-middle.

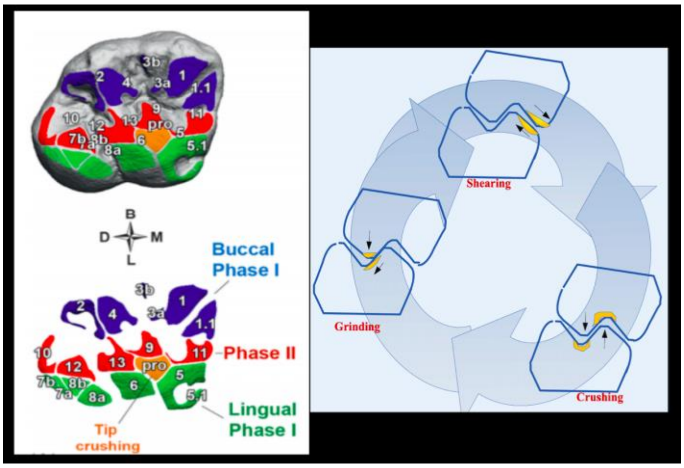

Figure 4: The occlusal pattern of wear of the first maxillary molars of Neanderthals. In the left is the 3D polygonal tooth-made and almost detached facets of wear classified into buccal phase I facets (blue), lingual phase I facets (green), phase II facets (red), and the tip crushing regions (orange) The right figure is the chewing process of foods in the molar tooth; it was labeled following the numbering systems developed by Maier & Schneck (1981)and Kay & Hiiemae (1974). Figure source: DOI: 10.1371/journal.pone.0014769.g001.

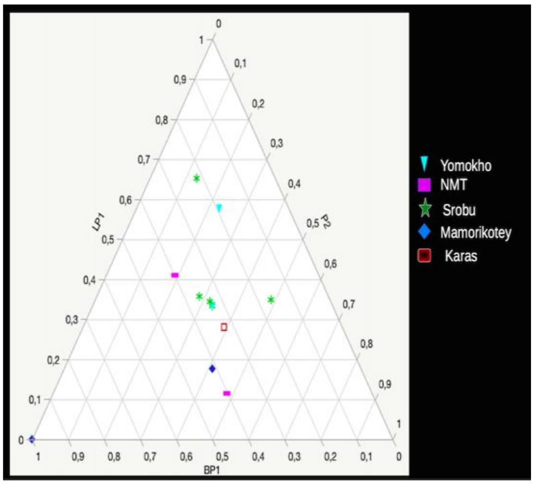

Figure 5. The ternary plot diagram presence the ratios of wear in the Buccal Phase 1, Lingual Phase 1, and Phase 2 of 20 molars teeth from the five sites (mamorikotey, namatota, yomokho, srobu, and karas). It is shown that the wear is distributed in all the area of the cycle phases.

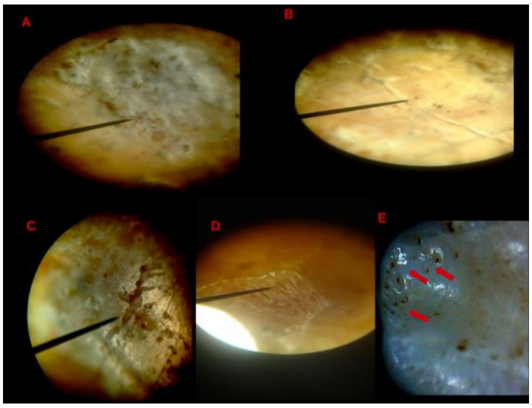

Figure 6. The microwear pattern in this study. A and b: the pattern of the line probably causes by the sharp object during mastication process; C, D, E, and F: pitting form of microwear.

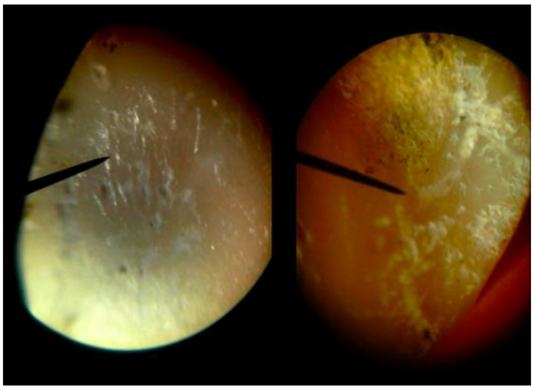

Figure 7. Microwear pattern in molar teeth from Srobu site.

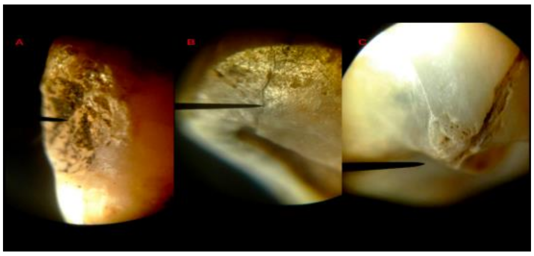

Figure 8. Microwear in Mamorikotey Site, A: MMK 79, UI2, B:MMK/49/UC, C:MMK/405/LP1.

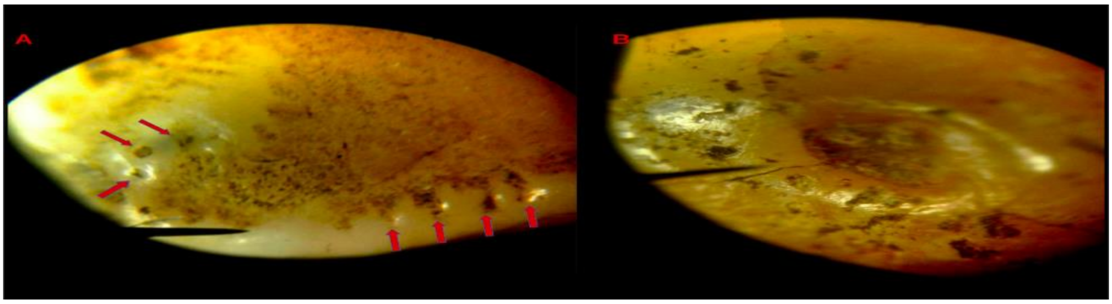

Figure 9. Karas Site Microwear, A: Krs/41/LC, B: Krs/649/UC.

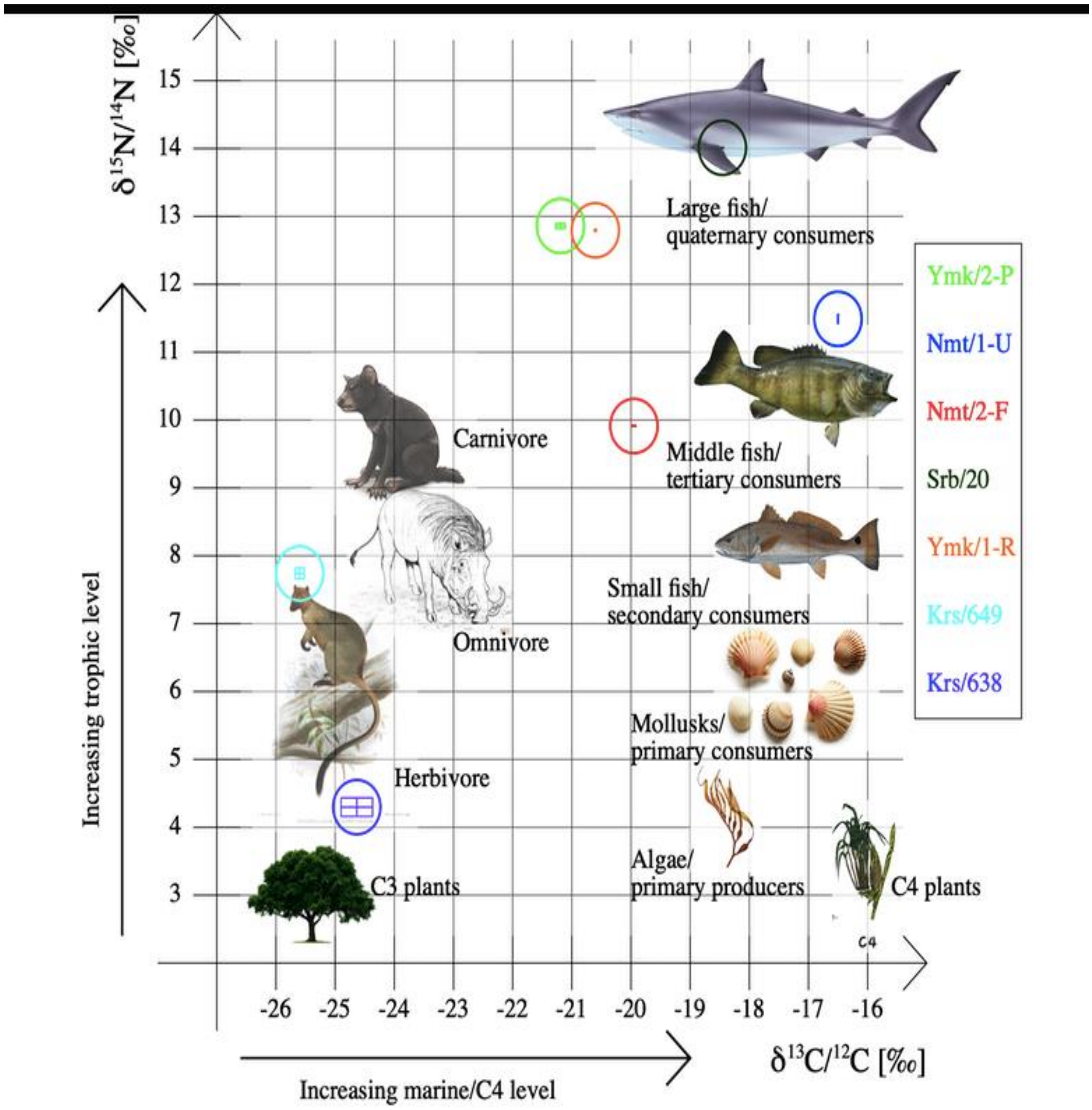

Figure 10. Typical Isotope δ13C and δ15N values of human bone collagen from 7 samples in this study. After establishing the food web isotopic values of local species based on the ecofact distributions, the bone collagen can be compared to determine if the source of dietary protein was more similar to plants only, herbivores, carnivores, or omnivores. The Yomokho site samples are abbreviated: YMK/1-R and YMK/2-P; the Namatota site has two samples: NMT/1-U and NMT/2-F; one sample from the Srobu site: Srb/20; two samples from karas site: Krs/638 and Krs/649 (Tolla, 2024).

Table 2. Descriptive statistics of wear facet areas of molar teeth from the five sites based on the chewing cycle phases described by (Kay & Hiiemae, 1974; Maier and Schneck 1981). Srb: Srobu, MMK: Mamorikotey, NMT: Namatota, Krs: Karas, YMK: Yomokho.

Site	N	Buccal Phase 1			Lingual Phase 1			Phase 2		
		Median	SD	IRQ	Median	SD	IRQ	Median	SD	IRQ
SRB	13	0,3333	0,0562	0	0,3333	0,0876	0,0108	0,3333	0,0746	0
MMK	2	0,7059	0,4159	0,2941	0,0882	0,1248	0,0882	0,2059	0,2912	0,2059
NMT	2	0,4005	0,0026	0,0018	0,2625	0,2087	0,1475	0,3371	0,2061	0,1457

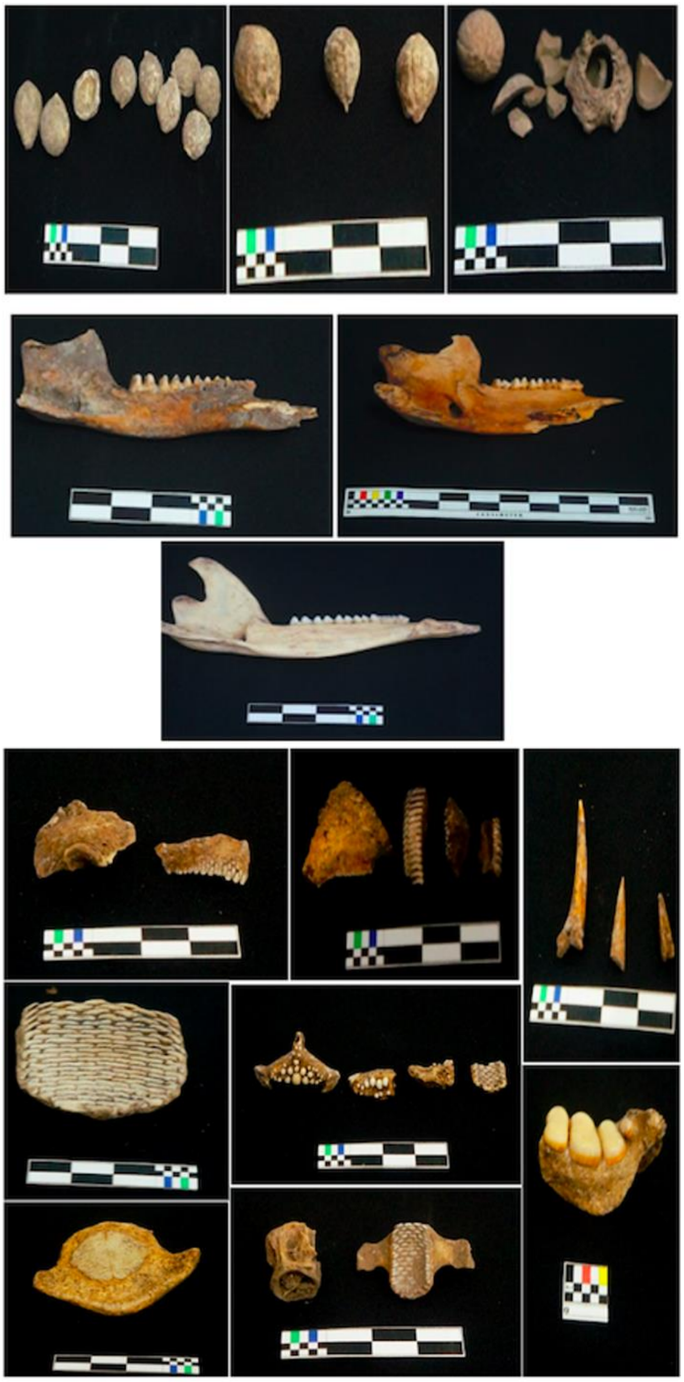

Figure 11. Ecofacts distribution from the five sites presents terrestrial plants and animals, as well as marine fish and mamalia.

Discussion

The primary function of human teeth is mastication, which causes a variety of physical features in the human tooth crown, such as wear. Food consumption is linked to physical and chemical elements that contribute to tooth wear (17). The hardness and texture of human food vary; it contains a chemical ingredient that promotes wear and tooth wear as consumption frequency increases. Mapping the areas of enamel loss by assessing the functional phases of the power stroke of mastication give us the ability to identify a diet behaviour by these people in the past (18). The chewing cycle methods used in this study provide various insights regarding diet behaviour and cultural patterns in past human groups, specifically the Late Holocene people in this study. The human teeth from the five sites in this research show wear on the most areas of the chewing part, lingual phase I, phase II, and buccal phase I. However, the differences are shown in terms of the frequency of wear in the chewing areas. The proportions of wear in the chewing phase between teeth are different in this term. The teeth from Namatota, Mamorikotey, and Srobu site had the larger wear in proportion to the buccal phase I, while the wear in the Yomokho and Karas teeth were found to be larger in lingual phase I and phase II. The dental relief in the Namatota teeth indicates that wear is most prevalent in the buccal phase I, followed by phase II, and lingual phase I which tend to be fewer in proportion (Table 2). The Mamorikotey teeth display slightly greater wear in the buccal phase I followed by modest wear in the phase II and lingual phase I. All occlusal locations of the teeth from the Srobu site were impacted by wear; however, buccal phase I was determined to have the highest slope of wear which exposed the dentine section. The relationship between tooth wear and diet type was studied to identify how wear patterns are created and what movements are responsible for the contacts on the occlusal surface (19, 20). The wear pattern in this study indicates that the chewing process was dominated by 'shearing' in buccal phase I with a horizontal in orientation. The 'shearing' process in buccal phase I reflects the food items eaten and the type of dental design and masticatory forces (18).

The information about the diet types obtained from bone collagen analisis (21) will be used to examine its relationship with the wear pattern generated in the human teeth in this study (Figure 10). The collagen 15N values for the teeth from Yomokho site (Ymk/2-P and Ymk/1-R) shows that piscivorous fish had been consumed, yet the collagen 13C value reveals that C3 plants have also been consumed. For the Mamorikotey site, the stable isotopes nitrogen ^{TM15}N and carbon ^{TM13}C are not available to MMK_333 and MMK_419. Only enamel apatite ^{TM13}C and ^{TM18}O show that the C3 plants were consumed during their childhood, and also they spent the childhood in the highland and not in the coastland part where the Mamorikotey is located. However, from the distribution of ecofacts in several layers associated with the human remains at this site, these individuals may spend their adult lives in the coastal part. The distribution of ecofacts is dominated by marine food remains, including fish bones from different species, sea mamalia, and seashells (21) (Figure 11). Beside this, pig bone remains consisting of dental and long bones were found in the layers of soil. Based on the available ecofacts, it can be stated that the types of foods consumed by these individuals during adult life consist of tough types of foods, which have a higher impact on the buccal phase I areas. For the Srobu teeth, the stable isotope collagen ^{TM15}N and ^{TM13}C from one sample tooth (Srb/20) imply the C3 plants of food consumption, including terrestrial meat and sea mamalias. The ecofacts discovered in the layer of soils at this site, which include marine fish and shell, marsupials, pig bones, fragmentary unidentify species of animal bones, and plant remains such as nuts, support a consumption of terrestrial meat, marine fish and C3 plants. The tough but soft foods and also foods with low abrasiveness, such as marine and terrestrial meat, require a high breakdown on mastication process (22, 23), particulary during the 'shearing' phase, which by this process gives significant wear on the buccal phase I of the teeth from the Yomokho, Mamorikotey and Srobu site. Namatota and Karas teeth possesed the most lingual phase I and phase II of wear (Table 2). Based on the results of the stable isotope of the teeth from these sites, the ratios present the collagen ^{TM15}N of 9,91 per mil and ^{TM13}C of 19,95 per mil on the NMT/2-F teeth, implies more terrestrial food were consumed from the Namatota site (21). This type of foods probably has an abrasive texture that requires a power stroke to crush. The food types with a rougher and abrasive texture involve additional transverse occlusal motions, which are often associated with a higher proportions of lingual phase I (18,34). The stable isotope study in sample Krs/649 from Karas site, presents the result of collagen ^{TM13}C with ratio of -25.68 per mil

indicates C3 plant consumption which is might be from animal and plant resources.
The macrowear appearance could be related to food preparations related to grit particles and dust that adhere to foodstuff (25). Artifacts associated with human teeth, such as pottery, mortars, pestles, and stone tools, may have contributed to tooth wear due to their use in food preparation. Artifacts associated with human teeth, such as pottery, mortars, pestles, and stone tools, may have contributed to tooth wear due to their use in food preparation. Archaeological findings, such as pottery, mortars, pestles, and stone tools, may have contributed to tooth wear due to their use in food preparation. Archaeological findings, such as mortars and pestles, are the product of past human cultural activities presenting evidence about their function as a food preparation tools. The type variation of mortars and pestles at the Mamorikotey, Yomokho, and Srobu suggests that tools be designed for flacking, cracking, pounding, and grinding grain, nuts and other plants foods (Figure 3). The rock grains as the raw materials of mortars and pestles may have accidentally separated from the core rock and entered mistakenly into the food items, becoming part of food consumed by these people in the past. The abrasive grit particles from stones can potentially cause microwear such as pits and scratches in the occlusal teeth (Figure 7 left). Ecofacts like as seeds and nuts have been found in the layer of soil associated with human remains from these sites, possibly as part of plant items processed with mortars and pestles. Enamel is the most mineralized and hardest tissue in the human body (26), which means that enamel is not easily worn but rather wears down when in contact with hard objects, including grit, sand, that come from the mortar and pestle. The bones from animal meet may also can contribute to the teeth abrasion in this study. The distribution of animals such as marsupials, pigs, and other mammalian species was mostly found in the five sites in this study which may accidentally cause abrasion in the teeth during meat consumption. Bones are composed of dense and hard material, which can be a trigger for abrasion in the teeth.
Two different wear forms were found on the teeth in this study: abrasion and erosion, impacting the loss of tooth tissue (enamel, dentin, and cementum). These wear types are the main problems in human teeth, which do not involve bacteria but eating behavior disorders (27). Based on the angle of wear planes in figure 7 (left), the abrasion on the enamel demonstrates the early phases of enamel loss as indicated by several dots of pits with irregular pattern on the occlusal area. By the time and frequency of its use in the mastication process, the development of abrasion encompassed practically the entire occlusal surface, while the abrasion depth into the enamel layer increased (figure 7, right). Enamel covers the entire crown of anterior (incisors and canines) and posterior (premolars and molars) teeth in humans, whereas dentin, cementum, and pulp are the inner tissues of human teeth. Enamel is formed by ameloblast cells and is made up of 96% inorganic crystals, making it the hardest substance in the human body (28), while dentin tissues covered by enamel contain 70% minerals and are the second hardest tissues after enamel (29). The hardness of the dentin and enamel tissues may protect the tooth from abrasion, attrition, and erosion during the mastication process. Nevertheless, in this study, the enamel and dentin on anterior and posterior teeth appear scarce, flat, and cupped in appearance (Figures 5, Figure 6, 7,8,9). The loss of enamel and dentin tissue may suggest that these people consumed abrasive foods in the past that were harder in texture than the enamel tissue substance. For example, monocotyledone plants with siliceious opal phytoliths containing abrasive particles harder than enamel have a Mohs scale grade of 1-10 (30). However, foods have diverse components with different physical and chemical properties: hard or elastic foods may generate mechanical differences during mastication rather than of abrasive effects on the enamel (31).
The wear pattern on the incisor and canines (Figure 9) shows that wear appears in a small area of the incisal part with an irregular shape and a deep scope. The appearance suggests that the worn area was frequently used for cutting and gnawing the abrasive food. The irregular shape and deep scopes of wear suggest that the foods being cut in this area may vary in hardness and type. The cusp tip and ridge of canines experience wear in various forms because of the abrasive texture of items like meals (27, 30, 31, 33). The pitting and scratching wear pattern in human canines is an indication of food consumption, which may derive from the category with higher grit and silica content, such as nuts and woody plants, as shown by the wear pattern in herbivorous animals' teeth (34, 35).
The plants obtained from foraging activities such as fruit, nuts, and leaves are abrasive in structure, which may have contributed to the microwear on the human teeth from the five sites. Considering the abrasion in the figure 6b, 6c, 7,

and 8b, it can be seen that the wear is a scratchy pattern with no significant width, which could be caused by an object or material with a point or sharp scratch. Based on the wear pattern shown in the upper and lower canines of human teeth from Karas site (Figure 9), four pits lined vertically from the distal marginal ridge corners to the incisal area. The pitting lines were found similar in the form and depth. The pitting form presents the clue that the upper and lower canines has been used for cutting the tough objects, which is a sharp edge or surface that have been attached to the canine area for cutting purposes. The object can be part of plants, the bones that attach to the meat as a part of food consumption. The particle silica deposited in plants such as fruits, seeds, and leaves, called phytolith, has been found to contribute to microwear patterns in prehistoric people, such as the population from the Lower Pecos region of Texas. The calcium oxalate in phytoliths was argued to have caused this microwear on the prehistoric human's enamel teeth at this site, as signified by the similarity of scratches in enamel teeth and the form of crystal points and edges in calcium oxalate phytoliths (36). Phytolith silicon dioxide is exceptionally strong and more durable than enamel tooth tissue, and consuming it may create microwear in human teeth. The phytoliths were also shown to be responsible for microwear in sheep's teeth after they ate phytolith-rich vegetables (37). In addition, the appearance of microwear in primates' teeth is caused by diet consumption, with a size range of 5–50 m produced from a small object such as phytoliths (38). Because the diet intake of the individuals from the five sites was formed by foraging activities, consumption of plants containing phytoliths may have been a regular component of diet consumed by the people from these sites in the past. Consumption of herbaceous plants, which contain more phytoliths, could be contributing to microwear patterns.

The second wear pattern discovered in the teeth in this study is erosion, which is defined as the loss of hard tooth tissues produced by the interactions of several variables such as chemical dissolution (acidic drinks and foods), biological factors (saliva), and chewing behavior (39). The erosion caused by the gradient left at the occlusal area, particularly in the molar teeth from the Srobu site, exhibits a severe range of wear, as indicated by flat teeth in all occlusal areas and exposed dentin on the surfaces. The severe stage of erosion is also established in the two premolar teeth of two different individuals from this site. Tooth erosion is caused by a combination of minerals dissolving by calcium being complexed by anions, the mineral extended by an attack from the hydrogen ion, and notably those with strong chelating actions, such as citric acid (40). This process is related to gastric acid regurgitated into the mouth, which causes tooth erosion development in human teeth across time and frequency of excessive gastric meal ingestion (41). The meat contained fats reflected in the tissue fatty acids (42,43), while marine foods, e.g., fish, also contain fatty acids, which vary among species (44), as has sbeen a part of human consumption in this study. Fats have several fatty acid compositions with distinct effects in the human body, which are modified by the biological system, particularly in ingestion, through several structural modification processes (45). The modification provoked several impacts; e.g., reflux problems in the human body resulted in regurgitated acid that provoked erosion in human teeth (41). Since the group of peoples in this study were relied on foraging and gathering wild foods including plants etc, the teeth erosion in this study may be caused by the consumption of organic acidic foods, e.g., high frequency and wide range consumption of acidic fruits or vegetables (44). This factor may promote the loss of enamel or dentin tissue throughout the chemical and physical properties (46).

Conclusion

Based on the chewing cycle methods applied in this study, all the teeth examined from the five sites showed wear in the most areas of the chewing part. However, the distinctions can be seen in terms of the frequency of wear present on the chewing areas. Based on the results of the bone collagen study, the different frequency of wear might be correlated with the types of food consumed by these people in the past. The type of diets which is based on the tough types of foods consumed by the individuals from Mamorikotey, Yomokho, and Srobu, has a higher impact of wear in the buccal phase I areas. The tough types of food from these sites including terrestrial meat and sea mammals which requires a high 'shearing' process in buccal phase I, further causes heavy worn in this area. Different from the teeth from Srobu, Mamorikotey, and Yomokho, the phase lingual I and phase II were found to have a high frequency of wear in the teeth from Namatota and Karas site. This evidence may correlate with the abrasive and rougher type of food texture, involved additional transverse occlusal motions, crushing and grinding process. The wear pattern on anterior and posterior teeth was found to be sparse, flat, and cupped, indicating abrasion, attrition, and erosion. While acidic foods may promote tooth erosion in this study, tooth abrasion may be caused by the ingestion of foods with a higher grit silica, food materials with a sharp surface or edge, derived from plants and bones or meat consumption. Because of the small sample size, it is difficult to draw general conclusions from the data of this study. However, this result can provide a hint and the basis of the future studies.

Declaration of Interest

None

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