Tooth wear among the indigenous Dayak Kenyah of Sungai Bawang village, East Kalimantan, Indonesia: a forensic anthropological perspective*

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Abstract

In forensic anthropology, tooth wear serves as a critical indicator of diet, age, and cultural practices. The Dayak Kenyah population is primarily involved in hunting and shifting cultivation. However, in this study population, they currently reside close to urban areas, where modernization may influence dietary habits. This study investigated clinical tooth wear in the modern-day Dayak Kenyah population, focusing on incisal and occlusal surfaces and their relationships with age and sex. Most participants exhibited mild to moderate wear, with incisal teeth showing greater wear than occlusal teeth. Age and tooth wear were positively related, while no significant differences were observed between male and female. The findings suggest that modernization may influence dietary habits, which in turn affect tooth wear, despite the population's partial retention of traditional practices such as hunting and shifting cultivation. These results highlight that cultural and diet changes affect tooth wear in indigenous populations.

Keywords: tooth wear; Dayak Kenyah; indigenous populations; forensic anthropology; modernization

Introduction

Tooth wear encompasses the processes of attrition, abrasion, and erosion (1). Attrition is the gradual loss of tooth substance due to contact between teeth during mastication or parafunctional activities; abrasion is the loss of tooth tissue resulting from frictional contact with non-dental substances; and erosion is the loss of dental hard tissue caused by non-bacterial chemical processes(2).From an anthropological perspective, tooth wear may document significant phases in human biological and cultural evolution, including indications of dietary resources employed by ancestral hominids, advancement of fire and cooking, creation of food processing techniques using grinding tools, transition to agriculture, invention of pottery, and other enhancements in food processing methods (3,4).

Numerous ancient populations exhibit significant tooth wear, and it has been proposed that all levels of wear can be considered physiological in these groups. However, in contemporary dentition, significant levels of tooth wear may not be considered normal (2,5), as the reduction in wear noted over the entire dentition appears to be a characteristic of contemporary industrialized countries (6).

There is a growing consensus that tooth wear seldom arises from a singular reason and that the wear evident in any individual may come from a confluence of various etiological events during the lifespan of the dentition. It can arise due to aging or result from environmental influences, such as the presence of grit in traditional diets. Cultural elements, such as using teeth as implements, may hold significance (2,7). Attrition may arise solely from tooth-to-tooth contact; however, dietary quality might contribute an additional abrasive or erosive factor to the wear (1,2).

The available research is lacking in information regarding tooth wear among the indigenous people of Indonesia. Indonesia exhibits three distinct morphologies (8), one of which is the Dayak from Kalimantan (Borneo). Dayak refers to the indigenous populations residing in Kalimantan, which constitutes the largest population on the island (9,10).The Dayak population is categorized into six principal groups: Kenyah-Kayan-Bahau, predominantly residing in eastern Kalimantan; Ot Danum, located in southern Kalimantan; Iban (Sea Dayak), inhabiting the northwestern interior and coastal regions of Kalimantan; Klemantan (Land Dayak), found in the northwestern hinterlands of Kalimantan; Murut, situated in northern Kalimantan; and Punan (Penan), located in the central to eastern areas of Kalimantan (11).

This study focused on the Dayak Kenyah population. They depend on the tropical rainforest of Kalimantan for sustenance and primarily engage in shifting cultivation, fishing, foraging, hunting, gold mining, and rice field cultivation (10). Traditional and indigenous populations subsist on meat, fish, and uncooked foods, rendering them susceptible to tooth wear (12). Nonetheless, the Dayak Kenyah population examined in this study resides near urban areas and may exhibit aspects of a modern lifestyle, which makes the population particularly suitable for examining the impacts of modernization on tooth wear while still retaining indigenous cultural practices. This study aimed to investigate the clinically observed tooth wear in relation to anthropological factors, age, sex, and dietary sources within the modern-day Dayak Kenyah population.

Materials and Methods

Study population

This study was conducted among Dayak Kenyah indigenous people residing in the Sungai Bawang Cultural Village, located in the Muara Badak District, Kutai Kartanegara Regency, East Kalimantan Province, Indonesia (13). According to local community leaders' estimates, the village comprises approximately 1,163 Kenyah residents, of whom about 307 individuals are aged 18–45 years. Participants within this age range were invited to join the study. The lower age limit (18 years) was selected because all permanent teeth are typically fully erupted by this age, allowing comprehensive assessment of tooth wear. The upper age limit (45 years) was chosen to minimize potential confounding factors such as periodontal disease and age-related tooth loss, which become increasingly prevalent in older adults.

A total of 70 subjects (38 male and 32 female) who met the inclusion criteria were enrolled. The inclusion criteria were as follows: (a) Class I occlusion, (b) absence of noticeable facial asymmetry, (c) no history of congenital anomalies or trauma affecting the head or face, and (d) absence of signs or symptoms indicative of temporomandibular disorders (TMD). Indigenous participants were defined as individuals whose parents had not intermarried with other ethnic or racial groups for at least two generations. This information was verified through interviews with family heads and, when

necessary, confirmed by local community leaders. Ethical approval for the study was obtained from the Ethical Committee of Airlangga University (No. 028/HRECC.FODM/III/2017), and all participants provided written and oral informed consent prior to participation.

Dietary survey

In addition to clinical examination, a brief dietary questionnaire was administered to all participants to provide contextual information on food consumption patterns. The questionnaire included basic questions about the primary sources of carbohydrates, proteins, and fiber consumed in daily meals. Responses were recorded as percentages based on the number of participants reporting each food item. The survey aimed to identify general dietary tendencies.

Assessment of tooth wear

Tooth wear was evaluated on an individual-tooth basis following the methodology of Lobbezoo and Naeije (2001) (14) and classified using a 5-point ordinal scale (0-4): Grade 0 = no wear; Grade 1 = visible wear limited to the enamel; Grade 2 = visible wear with dentin exposure and mild to moderate clinical crown height loss (≤1/3); Grade 3 = significant crown height loss (>1/3 but <2/3); and Grade 4 = crown height loss (≥2/3) as illustrated in Figure 1.

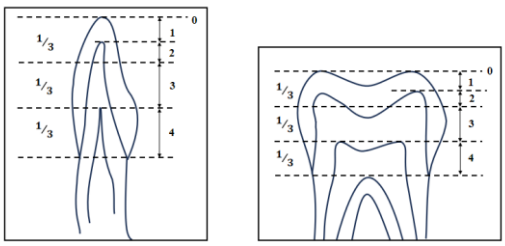

Figure 1. Tooth wear grading based on proportional crown height loss for anterior (left) and posterior (right) teeth. Wear was categorized into five grades (0-4). Each crown was visually divided into three equal thirds to estimate proportional loss.

Assessments were performed by direct visual inspection using a mouth mirror and a periodontal probe as a reference for crown height estimation. The examinations were conducted in a community-based setting at the Sungai Bawang Cultural Village. Two examiners independently assessed each tooth surface: incisal (anterior teeth: incisors and canines) and occlusal (posterior teeth: premolars and molars) in both the maxillary and mandibular arches.

For statistical analysis, a mean wear score per subject was calculated separately for anterior and posterior surfaces. The sum of ordinal scores for all anterior teeth was divided by the number of anterior teeth present in that subject, and the same approach was used for posterior teeth (15–18). These mean values represented the average ordinal wear per subject for each surface. Subjects were then grouped into wear categories (Groups 0-4) based on the subject's mean score: Group 0 (mean 0), Group 1 (mean 0.1-1), Group 2 (mean 1.1-2), Group 3 (mean 2.1-3), and Group 4 (mean 3.1-4). Age was treated as a continuous variable (years).

Examiner calibration and reliability

Two examiners independently assessed tooth wear according to the criteria described above. Prior to data collection, both examiners completed a calibration session using sample cases representing all wear categories. Inter-examiner reliability was then evaluated on all subjects (incisal and occlusal teeth) using Cohen's Kappa coefficient.

Statistical analysis

Data were analyzed using descriptive and inferential statistics to explore the relationship between tooth wear, age, sex, and dietary sources. Non-parametric tests were selected because the wear data were ordinal and did not follow a normal distribution. The Mann-Whitney U test was used to compare wear on tooth surfaces between males and females, while Spearman's rank correlation assessed the association between age and tooth wear for both incisal and occlusal surfaces. An effect size multivariate analysis was also conducted to examine the combined effects of age, sex, and dietary factors on tooth wear, with effect sizes (partial η^2) calculated to indicate the magnitude of associations. A P-value of < 0.05 was considered statistically significant. Analyses were performed using IBM® SPSS® Statistics version 23.0.

Results

Inter-examiner reliability

Inter-examiner agreement was assessed across all 70 subjects as shown in Table 1. The Cohen's kappa coefficients ranged from 0.841 to 0.939, indicating almost perfect agreement between examiners (19). Agreement was slightly higher in female subjects (incisal: 0.90; occlusal: 0.939)

than in male subjects (incisal: 0.841; occlusal: 0.863), confirming the consistency and reliability of the scoring procedure.

Modern-day tooth wear in the Dayak Kenyah population

The total number of cases (combined for male and female subjects) was represented through a bar chart (Figure 2) and supplemented with a frequency table (Table 2). The distribution revealed distinct differences between incisal and occlusal wear. As shown in Table 2, incisal teeth had elevated frequencies of mild to moderate wear, with 50% in group 1 and 22.86% in group 2. The occlusal teeth exhibited the highest percentage of people with no evident wear (group 0: 61.43%), followed by groups 1 (28.57%) and 2 (7.14%). This indicated that the incisal teeth were more susceptible to wear (Table 3). Significant wear (group 3) was noted in a limited number of individuals for both surfaces, and none of them attained the maximum wear level (group 4). The results demonstrated a prevailing tendency of wear severity in incisal teeth relative to occlusal teeth within the study group.

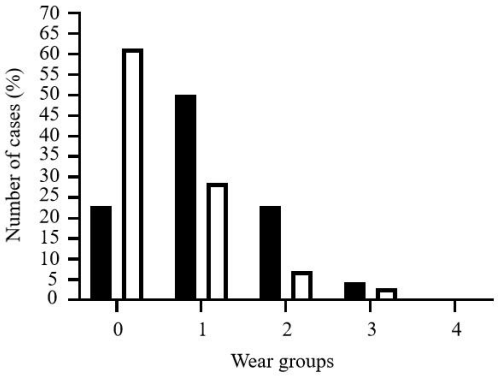

Figure 2. Histogram illustrating the distribution of cases among all studied Dayak Kenyah subjects in percentage based on incisal (black) and occlusal (white) tooth wear, with a wear group ranging from 0 to 4. No participants were present in wear group 4.

Dietary patterns

To provide context for the observed tooth wear patterns, a simple survey was conducted among the participants. The results showed that both male and female primarily consumed rice as their main carbohydrate source (male: 90.3%; female: 80.7%), with smaller proportions consuming cassava, corn, or sweet potatoes. Protein intake was more varied, with male reporting consumption of pork (31.3%), chicken (25%), fish (14.6%), and wild animals such as wild boar (6.2%). In contrast, female reported slightly higher intake of pork (38.6%) and plant-based protein from seeds (34.1%), but almost no consumption of wild animals. Fiber intake was dominated by vegetables in both sexes (male: 87.1%; female: 92.3%), while fruit consumption was lower (male: 12.9%; female: 7.7%).

Comparison of incisal and occlusal wear between males and females

Next, the wear surfaces of both males and females were analyzed as shown in Table 3. There were no significant differences in incisal or occlusal wear between males and females ($P > 0.9999$ and $P = 0.9048$, respectively). However, when the data were compared in incisal and occlusal wear of males and females, there were significant differences ($P = 0.0027$ and $P = 0.0005$, respectively), as well as in the combined sex-group ($P < 0.0001$).

Tooth wear related to aging

The correlation between the wear surfaces and aging was also analyzed. Table 4 shows the details of the statistical analysis of the relationship between wear surfaces and age, and Figures 3a and 3b show the scatter plot of this relationship for all the studied populations. A moderate positive connection was found between age and occlusal tooth wear in all individuals (Spearman $r = 0.5982$, $P < 0.0001$), indicating that occlusal wear worsens with age. A greater correlation was observed between age and incisal tooth wear (Spearman $r = 0.7492$, $P < 0.0001$), indicating that incisal are more likely to wear down over time. Both associations were statistically significant, indicating that age is an important factor affecting tooth wear, especially on the incisal.

Analysis of effect size multivariate of tooth wear in relation to age, sex, and dietary sources

The overall multivariate model, which included age, sex, and dietary sources (carbohydrate, protein, and fiber), was statistically significant for both incisal (P: 0.000, partial η^2: 0.304) and occlusal (P: 0.000, partial η^2: 0.210), indicating that these variables collectively explained a meaningful proportion of variance in tooth wear (Table 5). Among the individual predictors, age showed a strong and significant effect on both incisal and occlusal wear (P: 0.000; partial η^2: 0.532 and 0.393, respectively). In contrast, sex showed a weaker, non-significant effect on both incisal and occlusal wear ($P > 0.05$). Similarly,

dietary variables, including carbohydrate, protein, and fiber intake, showed no significant influence on wear (all P > 0.05). These findings indicate that age was the primary determinant of tooth wear in this population, while sex and dietary variation had minimal contributions.

tooth wear in various indigenous population (23,24).

The present study found that most subjects exhibited mild to moderate wear (groups 1-2), while severe wear (group 3) was uncommon, and no individuals showed extreme wear (group 4).

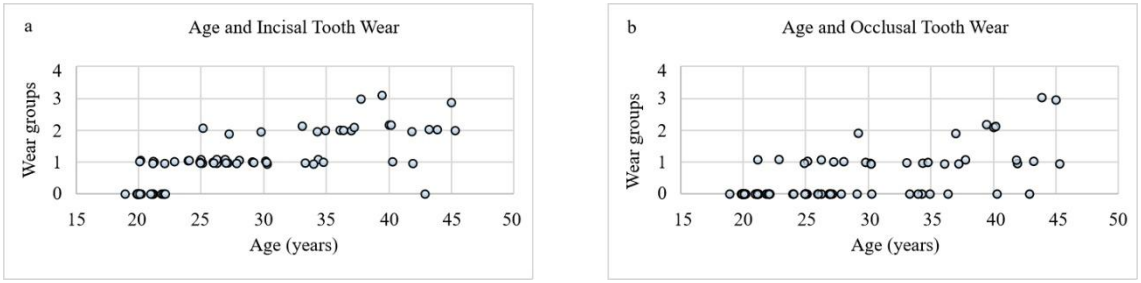

Figure 3. Correlation between age (years) and (a) incisal and (b) occlusal tooth wear in the observed Dayak Kenyah population. Age as a continuous variable (years). Wear groups for incisal or occlusal: 0 (mean: 0); 1 (mean: 0.1-1); 2 (mean: 1.1-2); 3 (mean: 2.1-3); 4 (mean: 3.1-4).

Tooth-wearing surfaces

In addition, each surface was overlooked for correlation. An obvious upward trend was observed between the incisal and occlusal surfaces in the scatter plot, but with some variability (see Figure 4). The results of the statistical analysis showed how these wear surfaces were highly correlated in the Dayak Kenyah population (Table 6). The analysis of all individuals showed a strong positive correlation, indicated by a Spearman's r value of 0.6458, and statistical significance with a P-value < 0.0001. The results indicates that those who wear down their incisal also wear down their occlusal.

Discussion

In physical anthropology, the degree of tooth wear and its circumstances are important indicators for examining the diet, age, and lifestyle of past populations. However, tooth wear is typically given little consideration in contemporary dentistry (20). Numerous studies on tooth wear in both prehistoric and modern populations have been conducted; yet few have focused on specific indigenous population with potential morphological and cultural differences.

This study was performed among the Dayak Kenyah population of East Kalimantan, an indigenous subgroup traditionally inhabiting the upper river regions of the island's interior (21). The Kenyah people traditionally practice shifting cultivation and hunting, with wild boar (Sus barbatus) being their primary protein source (22). Such dietary behaviors, involving coarse and fibrous food items, have been linked to increased

The finding may reflect the population's proximity to urban areas and adoption of a modern lifestyle, influencing diet and food preparation methods (23,25,26). Urbanization often influences traditional customs (27), yet they still engage in some subsistence activities such as hunting and shifting cultivation within Kalimantan's forest areas. Modern food processing, which softens foods texture, may contribute to reduced masticatory demand (28).

The relatively mild wear observed likely reflects a semi-traditional diet, which includes fibrous plant foods and locally processed staples containing trace abrasives. Findings from the dietary survey further support this interpretation, showing that the Dayak Kenyah diet remains predominantly rice based, with limited consumption of coarse or raw foods. Although fibrous vegetables and local staples are to be part of daily meals, the overall texture and preparation of food have likely softened due to modernization. When compared with earlier work from Sabah (29), which reported a high prevalence of moderate to severe wear in several ethnic groups in northern Kalimantan, our study revealed milder wear levels. These differences may be attributed to sampling age range, scoring criteria, and urbanization-related dietary changes.

A study comparing two periods among the Jomon and Edo populations indicated that food consumed by Japanese became softer, and the degree of attrition had also shown a decrease (20). Research on indigenous and urbanized populations in Greenland and Australia, present Eskimos and Australian Aboriginal communities indicates that tooth attrition diminishes with

urbanization (30,31). Modern humans, who consume more refined and processed foods, place less functional demand on their masticatory system compared to their ancestors did (32). Tough and fibrous foods require greater biting force and longer chewing time to be broken down adequately for swallowing, whereas softer foods are easier to process and provide less stimulation to the masticatory muscles and teeth (33).

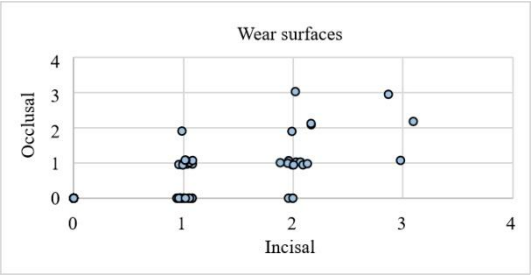

Figure 4. Correlation between the wear surfaces (incisal and occlusal) in the observed Dayak Kenyah population. Wear groups for incisal or occlusal: 0 (mean: 0); 1 (mean: 0.1-1); 2 (mean: 1.1-2); 3 (mean: 2.1-3); 4 (mean: 3.1-4).

A strong positive correlation was found between age and both incisal and occlusal wear, indicating that tooth wear tends to increase with age. This trend supports previous findings that wear progression often reflects the cumulative effects of lifelong mastication and functional use (2,5,20,34,35). However, it is important to note that tooth wear is not solely determined by chronological age. Behavioral and functional factors, such as the use of teeth as tools, dietary abrasiveness, parafunctional habits like bruxism, and individual variation in chewing force, can also significantly influence wear rates (7,36).

This study found no significant differences in tooth wear (incisal and occlusal) between males and females. Generally, wear tends to be more pronounced in males due to stronger masseter muscle activity, greater muscle mass, and higher occlusal forces (35–38). However, other studies have reported the opposite trend, where females exhibit greater tooth wear, possibly due to frequent food testing and fibrous food preparation (31,39–41). The comparable wear between sexes in the Dayak Kenyah group may reflect shared dietary habits and social roles, minimizing sex-based behavioral differences in masticatory use.

Tooth wear was analyzed by surface type: incisal (anterior) and occlusal (posterior). On average, incisal wear was more pronounced than occlusal wear. Posterior teeth are primarily responsible for processing food texture, while anterior teeth reflect both dietary and behavioral functions (42). This outcome aligned with the conclusions of other researchers. The greater incisal wear may result from thinner enamel, smaller tooth size, and their involvement in excursive movements and parafunctional activities (43,44). Furthermore, earlier eruption of anterior teeth exposes them to wear for a longer duration (37, 43).

A limitation of this study is the use of a clinical ordinal scoring system, which provides only a categorical assessment of wear severity. More advanced techniques, such as 3D superimposition and intra-oral scanning, now allow precise and quantitative measurement of tooth wear progression (36,46). These digital approaches not only enhance measurement accuracy but also enable standardized comparisons across populations and time points, thereby reducing examiner bias.

Another limitation concerns the age range of the participants (18–45 years). Because older adults were not included, the findings may not represent the full extent of tooth wear within the broader Dayak Kenyah population, particularly at more advanced ages where severe wear and tooth loss are more common. In addition, the dietary information collected in this study was self-reported and limited to broad food categories, without quantifying food hardness, chewing frequency, or other behavioral habits that could influence tooth wear. Future studies incorporating quantitative dietary analysis and digital wear assessment techniques would provide a more comprehensive understanding of the relationship between lifestyle, diet, and tooth wear in indigenous population.

Conclusions

Most of the Dayak Kenyah people had mild to moderate tooth wear. The majority of mild wear may be due to the dietary softening that comes with modern lifestyles near urban areas, despite the people still continuing to practice traditional methods such as hunting and shifting cultivation. The incisal teeth showed more wear than the occlusal teeth. Age and tooth wear were linked, and no significant differences were observed between males and females. These results suggest that cultural and diet changes affect tooth wear in indigenous populations.

Tabel 1. Inter-examiner Cohen's kappa coefficients for incisal and occlusal wear.

	Incisal	Occlusal
Male	0.841	0.863
Female	0.900	0.939

Kappa coefficients indicate the level of agreement between two examiners in assessing incisal and occlusal wear in male and female subjects.

Table 2. Incisal and occlusal wear prevalence.

Sex	N	Wear groups N (%)									
		0		1		2		3		4	
		I	O	I	O	I	O	I	O	I	O
Male	38	9 (23.68)	24 (63.16)	19 (50)	8 (21.05)	7 (18.42)	4 (10.53)	3 (7.9)	2 (5.26)	0 (0)	0 (0)
Female	32	7 (21.88)	19 (59.38)	16 (50)	12 (37.5)	9 (28.12)	1 (3.12)	0 (0)	0 (0)	0 (0)	0 (0)
Total	70	16 (22.86)	43 (61.43)	35 (50)	20 (28.57)	16 (22.86)	5 (7.14)	3 (4.28)	2 (2.86)	0 (0)	0 (0)

Reported wear groups are based on the mean subject wear score per surface. For each subject, the average ordinal score across all anterior teeth (incisal: I) and across all posterior teeth (occlusal: O); subjects were then assigned to group 0-4 based on that mean: 0 (mean: 0); 1 (mean: 0.1-1); 2 (mean: 1.1-2); 3 (mean: 2.1-3); 4 (mean: 3.1-4); N, the total number of subjects; %, the percentage of the subjects (male, female, or all individuals)

Table 3. Comparison of wear surfaces and sex.

Wear surfaces and sex			P-value
Incisal wear males	vs	Incisal wear females	>0.9999
Occlusal wear males	vs	Occlusal wear females	0.9048
Incisal wear males	vs	Occlusal wear males	0.0027
Incisal wear females	vs	Occlusal wear females	0.0005
Incisal wear males and females	vs	Occlusal wear males and females	<0.0001

P-value, the probability value for wear surfaces (incisal or occlusal) and sex (male or female) as determined by the Mann-Whitney test (significantly different, P < 0.05)

Table 4. Correlation of wear surfaces with age.

Sex	N	Wear surfaces			
		Incisal		Occlusal	
		r	P-value	r	P-value
Male	38	0.7155	<0.0001	0.5914	<0.0001
Female	32	0.7583	<0.0001	0.6155	0.0002
Total	70	0.7492	<0.0001	0.5982	<0.0001

Age as a continuous variable (years). N, number of subjects; P-value, probability value for male and female age and wear surfaces as assessed by Spearman's rank correlation (significant correlation, P < 0.05); r, correlation coefficients.

Tabel 5. Effect sizes multivariate analysis among tooth wear, age, sex, and dietary sources.

Wear surfaces							Carbohydrate		Protein		Fiber	
	P-value	Partial η^2	P-value	Partial η^2	P-value	Partial η^2	P-value	Partial η^2	P-value	Partial η^2	P-value	Partial η^2
Incisal	0.000	0.304	0.000	0.532	0.365	0.047	0.267	0.058	0.081	0.096	0.148	0.077
Occlusal	0.000	0.210	0.000	0.393	0.202	0.067	0.698	0.021	0.181	0.071	0.775	0.017

Age as a continuous variable (years). P-values and partial η^2 (effect size) are shown for wear surfaces (incisal and occlusal). Significant P < 0.05.

Table 6. Correlation between the incisal and occlusal wear of the subjects.

Sex	N	r	P-value
Male	38	0.6946	<0.0001
Female	32	0.5711	0.0006
Total	70	0.6458	<0.0001

N, number of subjects; P-value, probability value for wear surfaces as assessed by Spearman's rank correlation (significant correlation, $P < 0.05$); r, correlation coefficients.

Declaration of Interest

None

Author Contributions

MIM: conceptualization, formal analysis, methodology, writing original draft, review & editing, supervision; AC: writing original draft, methodology; BNR: writing original draft, methodology; AK: formal analysis, methodology, writing original draft, review & editing.

Statement on the use of artificial intelligence in manuscript preparation

The authors declare that artificial intelligence (AI) tools were used to support the preparation of this manuscript. These tools assisted only in language refinement, grammar correction, and improvement of sentence clarity and readability. The authors take full responsibility for the content of the manuscript.

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