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Research Paper

Prevalence and Sexual Dimorphism of the Mesial Marginal Developmental Groove in Maxillary Premolars: A Study in the Malay Population

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ABSTRACT

Background: Forensic odontology is essential for human identification when DNA or fingerprinting is compromised. Postmortem identification uses teeth because they resist environmental degradation and may remain intact under extreme conditions. While dental morphological traits are useful in forensics, population-level data are needed before using them in identification protocols. Mesial marginal developmental groove (MMDG) data in maxillary premolars in Malay are scarce. To determine the prevalence and sexual dimorphism of the MMDG in maxillary premolar one and two (PM1 and PM2) among Malay patients.

Methods: One hundred ninety plaster dental casts were retrieved from the Orthodontic Department. Standardised photographs of the occlusal surface of maxillary PM1 and PM2 were assessed for the presence or absence of MMDG. Descriptive statistics were employed to determine prevalence, and Chi-square tests were performed to evaluate sexual dimorphism.

Results: MMDG prevalence in PM1 was 90.5%–93.2% and 53.7%–57.4% in PM2, with bilateral symmetry observed across all tooth types. No significant sexual dimorphism was determined in the prevalence of MMDG for all tooth types.

Conclusion: The MMDG in maxillary premolars showed no sexual dimorphism in Malay people, limiting its use in forensics. However, its high prevalence and bilateral consistency make MMDG a stable morphological marker for dental identification and population studies.

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Introduction

Forensic odontology (FO) applies dental knowledge to legal and investigative matters, most notably in identifying human remains through orofacial structures [1, 2]. Forensic dental analysis is essential when DNA evidence is unavailable due to contamination or biological degradation, and fingerprint analysis is precluded by soft tissue decomposition. Teeth with 96% inorganic minerals are the strongest body structure, which makes them resistant to fire, water, soil, biological, and chemical agents. Natural disasters, air and road traffic accidents, terrorist attacks, and wars benefit from dental evidence [3, 4].

Forensic comparative identification compares antemortem and postmortem dental records to identify restorations, prostheses, tooth morphology, and eruption patterns. Dental profiling is done to estimate age, sex, and ancestry without antemortem records [5, 6]. To characterise population-level prevalence and assess sexual dimorphism, tooth morphology has been extensively studied using morphometric and non-metric methods [7–9]. Early odontogenesis genetic and epigenetic mechanisms regulate non-metric dental traits, which are distinctive morphological features of the tooth crown. Because post-eruptive environmental factors rarely affect these traits, they are good population affinity and biological profiling markers.

Ethnic group data is population-specific and cannot be applied to another [10, 11]. Within the Malay population, several dental traits have been examined, which demonstrated the applicability of odontometric measurements for sex prediction in Malaysians [12], as well as population-level variation in crown morphology across different Malaysian ethnic groups [11]. A study examined the sex-predictive power of maxillary posterior tooth occlusal characteristics in the same population, with above 75% accuracy [6].

Maxillary first premolars (PM1) are distinguished by their non-metric groove on the mesial marginal ridge, known as mesial marginal developmental groove (MMDG) [13], which can serve as a forensic and anthropological marker due to its bilateral expression and population-specificity. Dental profiling and comparative population studies can benefit from MMDG prevalence in Malay maxillary premolars, as consistent population traits may be useful morphological indicators for dental identification, especially when fragmented or isolated teeth are recovered [14, 15]. Thus, baseline prevalence data assist forensic odontologists in determining whether a trait is stable or sporadic [16]. This study examines the prevalence of MMDG in maxillary premolars and its potential for sexual dimorphism in Malay people.

Materials and Methods

A cross-sectional observational study was conducted after ethical approval [XXX 2025-110] to comply with institutional research governance. PS Power and Sample Size software version 3.1.2 calculated the sample size, and 190 plaster dental casts of Malay patients (95 males and 95 females) were retrieved from the Department of Orthodontics archives. Only casts with clear access to maxillary premolar morphology were included.

Standardised occlusal photographs of the selected teeth were captured using a high-resolution digital camera under consistent lighting and magnification conditions (Figure 1). Images were then evaluated for the presence or absence of the MMDG on the right-sided PM1 (PM1R), left-sided PM1 (PM1L), right-sided PM2 (PM2R), and left-sided PM2 (PM2L). MMDGs were defined as grooves crossing the mesial marginal ridge and scored using a binary classification system

Figure 1. Digital images captured using cellphone with high resolution camera.

(present/absent) according to morphological scoring criteria (Figure 2) [10].

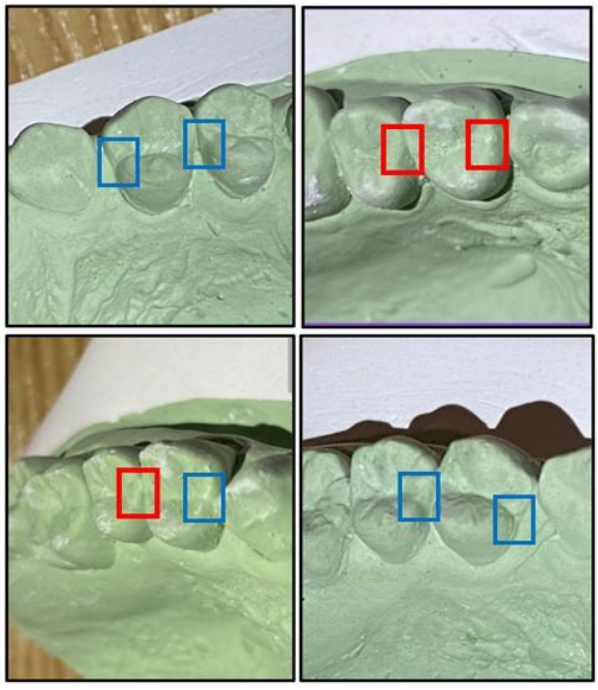

Figure 2. Digital images of maxillary premolars to record absence (red box) or presence (blue box) of the MMDG.

Statistical Analysis

Data were analysed using IBM SPSS 30. The Intraclass Correlation Coefficient (ICC) and a two-way mixed-effects model for absolute agreement were used to assess intra- and inter-examiner reliability. An ICC above 0.90 indicates excellent reliability [17]. Descriptive statistics were used to determine MMDG prevalence in males and females across tooth types, while Chi-square tests were used to determine sexual dimorphism. Statistical significance was set at $p < 0.05$.

Results

ICC values of 1.00 were found for intra- and inter-examiner comparisons, indicating MMDG presence or absence scoring consistency across repeated and independent assessments. These results show that this study's morphological scoring was highly reproducible and that observer variability did not cause dataset errors.

Table 1 shows male and female MMDG prevalence in the study population. PM1R had 91.6% males and 94.7% females with MMDG, totaling 93.2%. MMDG was found in 90.5% of PM1L samples, 91.6% in men, and 89.5% in women. PM2R had 58.9% males and 55.8% females with 57.4% MMDG, while PM2L had 55.8% males and 51.6% females with 53.7% groove prevalence. Both sides of maxillary PM1 had over 90% MMDG, while it was low in PM2 (53-57%). The PM1 MMDG is highly consistent but more variable in the PM2 (Table 1).

Table 1. Prevalence of MMDG in maxillary premolars in Malay population.

Tooth type	Male (%)	Female (%)	Overall (%)	Overall Absent (%)
PM1R	91.6	94.7	93.2	6.8
PM1L	91.6	89.5	90.5	9.5
PM2R	58.9	55.8	57.4	42.6
PM2L	55.8	51.6	53.7	46.3

Bilateral symmetry between PM1 and PM2 was assessed using McNemar's test, which showed no significant sexual dimorphism ($p > 0.05$), indicating symmetrical distribution of the studied trait. Therefore, either side may be used in future analyses, with the contralateral tooth serving as a substitute when one side is missing. Sexual dimorphism was analysed using the Chi-Square test. Overall, no statistically significant sexual dimorphism was observed in all the tooth types (Table 2).

Table 2. Sexual dimorphism for the presence of MMDG in maxillary premolars.

Tooth type	Chi-Square Value (χ^2)	df	p-value
PM1R	0.743	1	0.389
PM1L	0.245	1	0.620
PM2R	0.194	1	0.660
PM2L	0.339	1	0.561

Discussion

Dental anthropological research has long used non-metric dental morphological traits because they resist post-eruptive modification and are genetically determined [18]. This study examined the prevalence of the MMDG on maxillary premolars in Malay people, focusing on bilateral symmetry and sexual dimorphism. The MMDG was highly prevalent in the PM1s, with bilateral prevalence exceeding 90% in both sexes, while PM2 demonstrated considerably more variable expression (Table 1), suggesting that the MMDG is a less constant feature in PM2. These findings are consistent with classical anatomical descriptions, which identify MMDG as a defining feature of the PM1

that is less consistently expressed in the PM2 [13, 19]. The high prevalence observed in PM1 is consistent with East Asian and Southeast Asian data [20]. Marginal groove traits tend to exhibit population specificity, with higher expression rates in Asian-derived groups compared to European populations [18], which further supports this pattern within the Malay ethnic group.

Recent dental anthropology studies emphasize population-specific non-metric dental traits. Race and geography strongly influence marginal grooves, accessory cusps, and fissure patterns in crown morphology and accessory dental features [21]. Thus, forensic interpretations of these traits must use locally derived datasets rather than extrapolated values from unrelated populations. For biological profiling and comparative identification, modern forensic dental literature recommends regional dental trait prevalence databases [22].

Anthropology and forensic odontology record dental morphology where the morphological markers reveal tooth type and population-specific dental traits. This study found that maxillary PM1 had the MMDG, suggesting it is a stable Malay anatomical trait rather than a sporadic morphological variation.

The forensic applicability of dental trait identification protocols requires baseline prevalence data to create regional dental morphology reference databases [23]. These databases aid Southeast Asian forensic investigations with limited dental morphology. This study establishes Malay comparative and forensic dental baselines. The Malaysian population has shown minimal sex differentiation in non-metric crown morphological traits, like Carabelli's trait on the maxillary first molar and groove patterns on mandibular premolars [6, 11, 24]. Tooth dimensions show sexual dimorphism in human dentition, with males having larger values due to longer growth periods and androgenic hormonal influences during odontogenesis [25, 26]. In contrast, polygenic genetic and epigenetic mechanisms regulate non-metric traits, such as the MMDG, during early crown development, with minimal hormonal modulation post-partum [10, 27]. Hence, our study findings are biologically plausible and consistent with the theoretical framework governing non-metric trait expression. MMDG bilateral symmetry in this study supports the idea that groove formation is primarily controlled during the bell stage of odontogenesis, when enamel organ–dental papilla interactions establish crown morphology [29]. Shared genetic and epigenetic regulatory mechanisms cause enamel knot signalling centres to replicate bilaterally, directing cusp and groove patterning [30]. Thus, genetic and morphological stability of MMDG expression is supported by bilateral symmetry [12,31]. Comparatively, a study found significant sexual dimorphism in South Asian maxillary premolars, with males showing larger buccolingual dimensions, intercuspal width, and tooth weight. [28]. These findings prove metric analysis is better at detecting premolar sexual dimorphism. The evidence suggests that biological profiling's non-metric MMDG sex indicator is unreliable. Multivariate models with odontometric parameters may improve it.

War, aviation, and natural disasters leave fragmented, charred, or isolated dental remains. Morphological tooth type identification is crucial under these conditions. An isolated tooth fragment with above 90% bilateral MMDG on PM1s may help reconstruct the dental arch and narrow the comparison with antemortem records. However, MMDG sex estimation is limited by the lack of significant sexual dimorphism. Biological profiling relies on dental sex determination when skeletal indicators are unavailable or poorly preserved [15, 31]. Thus, MMDG should be avoided as a sole or primary criterion in sex determination protocols or should not be given inferential weight.

Despite its limitations, the MMDG aids multivariate analysis. Adding metric and non-metric dental traits to composite scoring or discriminant function models improves forensic odontology biological profile estimation [32,33]. Tooth dimensions need to be utilised in such models because of their high prevalence, developmental stability, and population-specific expression. Subsequent logistic regression or discriminant function analysis may demonstrate the incremental predictive value of the MMDG alongside complementary variables.

These findings demonstrate that population-specific reference data are necessary for valid and ethical identification protocols using any morphological or metric trait in forensic odontology [34]. Dental morphological norms are not universally transferable across ethnic groups, and the application of data derived from dissimilar populations risks systematic error in biological profiling [35]. The findings of this study add to the growing repository of locally derived dental reference standards needed for accurate forensic identification in Malaysia and Southeast Asia [32]. Dental structures often survive extreme post-mortem conditions, hence morphological traits can identify people when other methods fail. From common and stable population traits, forensic odontologists can identify tooth types, reconstruct dental arches, and narrow comparisons with antemortem dental records [36].

This study was conducted on the Malay ethnic group of the Malaysian population. Hence, findings may not be generalisable to other Malaysian populations

Conclusion

MMDG prevalence and sexual dimorphism in maxillary premolars were studied, thereby filling a gap in the Southeast Asian morphological dataset. PM1 stability and population association were confirmed by its high MMDG levels and bilateral expression. PM2 groove expression varied more, suggesting a different developmental threshold. No significant sexual dimorphism was found in MMDG premolars. Thus, the MMDG alone cannot reliably estimate sex in forensic dental profiling in this population, but multivariate analyses with metric dental measurements may be useful. These findings support the use of regional forensic dental identification and population-specific dental morphological databases.

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Conflicts of Interest

The authors report there are no competing interests to declare.

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