

## OCCLUSAL MORPHOLOGICAL VARIABILITY OF CONTRALATERAL UPPER FIRST MOLARS IN RELATION TO TOOTH WEAR: A 3D GEOMETRIC MORPHOMETRIC STUDY

Diana CERGHIZAN<sup>1</sup>, Cristina Stanca MOLNAR VARLAM<sup>1,\*</sup>, Sorin-Claudiu POPȘOR<sup>1</sup>

<sup>1</sup> "George Emil Palade" University of Medicine, Pharmacy, Science, and Technology, 540139 Târgu-Mures, Romania

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### Abstract

Occlusal wear progressively modifies molar morphology and may reduce contralateral dental similarity. Our study evaluated intraindividual contralateral occlusal morphological similarity of permanent upper first molars across different wear stages using three-dimensional geometric morphometrics. Methods: A retrospective observational study was performed on 90 adult subjects contributing 180 contralateral permanent upper first molars. The sample was divided into three equal groups according to occlusal wear stage. Digital models were analyzed using landmark-based three-dimensional geometric morphometric methods. Procrustes distance, centroid size difference, occlusal asymmetry index, and regional deviation scores were compared across wear stages. Results: Contralateral morphological similarity decreased progressively with increasing tooth wear. The lowest Procrustes distance and occlusal asymmetry index were observed in wear stage 1, whereas the highest values were recorded in wear stage 3. Centroid size discrepancy also increased with wear progression. Regional analysis showed the greatest deviation in the palatal cuspal area, particularly at the level of the hypocone and protocone. Conclusions: Tooth wear was associated with reduced contralateral occlusal similarity and increased regional morphological asymmetry. These findings suggest that contralateral upper first molars become less reliable as anatomical templates as occlusal wear advances.

**Keywords:** upper first molar, occlusal wear, geometric morphometrics, contralateral symmetry, dental morphology, digital models.

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### Introduction

Occlusal morphology is a dynamic biological structure shaped by the interaction between inherited crown form, enamel distribution, masticatory function, and progressive tooth wear. In molars, this interaction is particularly relevant because occlusal anatomy is not only a product of developmental patterning, but also of functional loading over time. Recent work on enamel thickness per masticatory phases has shown that wear does not affect the crown uniformly and that the relationship between enamel distribution and macrowear is region-dependent, supporting the view that occlusal morphology must be interpreted as a functional rather than purely static anatomical entity [1]. This perspective is reinforced by studies of fossil

and recent dentitions, where molar form, tissue distribution, and wear-related remodeling are closely linked to developmental and biomechanical constraints [2,3].

Among permanent teeth, molars display substantial phenotypic variability, yet this variability is structured and partially under genetic control. Intercuspal dimensions have been shown to reflect a significant genetic contribution to molar phenotypic variation, indicating that the spatial arrangement of cusps and occlusal surfaces is not random [4]. At the same time, bilateral dental structures are expected to retain a high degree of symmetry, which makes contralateral comparison a useful framework for evaluating normal variation and deviation from an individual-specific pattern. This concept has recently been explored in endodontic and micro-computed tomography studies, where contralateral teeth demonstrated relevant anatomic similarity, supporting the idea that paired teeth may serve as biologically meaningful reference units [5,6].

Tooth wear introduces an additional level of complexity to this bilateral relationship. Functional wear progressively modifies cusp height, intercuspal relief, and occlusal topography, while preserving, to a variable extent, the underlying morphological framework. Previous studies have shown that molar inclination is physiologically linked to macrowear pattern and that enamel–dentin junction morphology and outer enamel surface morphology are not affected identically by variation in crown form and function [7,8]. Moreover, recent geometric morphometric approaches have demonstrated that asymmetry can be quantified with high sensitivity, opening the possibility of detecting subtle shape divergence between contralateral teeth beyond conventional linear measurements [9].

The quantitative study of occlusal wear has also advanced substantially through digital methods. Occlusal Fingerprint Analysis has provided a reproducible framework for the assessment of wear distribution and contact-related surface modification, highlighting the functional significance of wear patterns rather than merely their extent [10]. This is clinically relevant because restorative and prosthodontic decision-making increasingly depends on the accurate reproduction of individualized occlusal anatomy [11]. At the same time, dental phenotypes continue to be used as highly informative biological markers in studies of population history and taxonomic variation, emphasizing that crown morphology retains both functional and biological meaning even under progressive wear [12,13].

From a developmental perspective, enamel thickness and crown architecture are strongly influenced by genetic determinants, which in turn may affect how wear is expressed on the occlusal surface [14-18]. Therefore, accurate morphometric investigation of molar wear requires reliable digital acquisition protocols. In this context, standardized digitizing methods for indirect restorations and high-fidelity digital model acquisition are essential to ensure precision and reproducibility in three-dimensional morphological analysis [16-19].

In light of these considerations, our study aimed to evaluate intraindividual contralateral occlusal morphological similarity of permanent upper first molars across different stages of tooth wear using a three-dimensional geometric morphometric approach.

## **Materials and Methods**

### ***Study design and sample selection***

This is our retrospective observational study, which included 90 adult subjects contributing 180 contralateral permanent upper first molars. The sample comprised 45 females and 45 males and was divided into three groups according to the degree of occlusal wear: wear

stage 1, wear stage 2, and wear stage 3, with 30 individuals in each group. The inclusion criteria were age  $\geq 18$  years, bilateral presence of permanent upper first molars, complete occlusal eruption, availability of digital dental models suitable for three-dimensional analysis, and clear assignment to one of the predefined occlusal wear stages. The exclusion criteria included extensive carious destruction, crowns or large occlusal restorations, major coronal fractures, marked developmental anomalies, severe loss of occlusal landmarks preventing reliable landmark placement, previous orthodontic or prosthetic modification affecting occlusal morphology, and digital models with artifacts or incomplete surface capture. Our study was conducted in accordance with the Declaration of Helsinki. Owing to the retrospective design and the use of anonymized digital records, informed consent was waived or obtained in accordance with institutional regulations.

#### ***Digital model acquisition and wear stage classification***

All included teeth were analyzed on digital dental models obtained by optical scanning and exported in a format suitable for three-dimensional morphometric assessment. We have only included scans with adequate resolution and clear representation of the occlusal surface. For each subject, the contralateral permanent upper molars were identified and isolated for analysis. Occlusal wear was assessed using a predefined three-stage classification based on the extent of cusp flattening and occlusal surface modification. Wear stage 1 included minimal wear with preserved cusp morphology, wear stage 2 represented moderate wear with evident flattening but preserved major occlusal landmarks, and wear stage 3 included advanced wear with more pronounced cusp reduction and occlusal remodeling, while still allowing reliable landmark identification.

#### ***Geometric morphometric analysis***

We performed a three-dimensional geometric morphometric analysis to assess the intra-individual contralateral similarity of the upper first molars. A standardized set of anatomical landmarks and semi-landmarks was placed on the occlusal surface of each tooth, covering the main cusp regions, central fossa, and marginal ridges. We have consistently performed landmark placement for all specimens to capture both the overall morphology of the crown and the regional occlusal variation. After the baseline acquisition, we subjected the configurations to Generalized Procrustes Analysis (GPA) to eliminate the effects of position, orientation, and scale. The main morphometric variables extracted from the analysis included Procrustian distance, centroid size difference, occlusal asymmetry index, and regional deviation values for protocon, hypocone, paracon, metacon, central fossa, and marginal ridges. We used these parameters to quantify the discrepancy in shape and local morphological variation between the contralateral molars.

#### ***Outcome variables***

The main result of our study was intra-individual contralateral morphological similarity according to the stage of occlusal wear. This was assessed using Procrustes distance, centroid size difference, and occlusal asymmetry index. The secondary outcome was regional occlusal morphological variation, assessed by comparing mean deviation scores in the main occlusal regions. For comparative purposes, the three wear stage groups were analysed both in relation to the overall morphometric similarity and in the regional distribution of morphological changes.

Particular attention has been paid to the relative involvement of the palatal cuspal area, the buccal cuspal area, the central fossa, and the marginal ridges.

### ***Statistical analysis***

We performed the statistical analysis using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean  $\pm$  standard deviation (SD), while categorical variables were presented as numbers and percentages. Comparisons between the three groups of occlusal wear were made using appropriate tests depending on the type of data and distribution. Continuous variables were analyzed using one-way analysis of variance (ANOVA) or the corresponding nonparametric alternative, when necessary, while categorical variables were compared using the chi-square test. A p-value of 0.05 was considered statistically significant.

## **Results**

### ***Sample characteristics and distribution of occlusal wear***

A total of 90 adult subjects were included in the study, contributing 180 contralateral permanent upper first molars. The sample comprised 45 females (50.0%) and 45 males (50.0%), with a mean age of  $29.8 \pm 6.4$  years. According to the degree of occlusal wear, the subjects were allocated into three groups of equal size: wear stage 1, wear stage 2, and wear stage 3, with 30 individuals in each group. Mean age increased progressively across wear stages, whereas sex distribution remained balanced among the groups. The baseline characteristics of the study sample are summarized in Table 1.

**Table 1.** Sample characteristics and distribution of occlusal wear

Variable	Wear Stage 1 (n = 30)	Wear Stage 2 (n = 30)	Wear Stage 3 (n = 30)	Total (n = 90)	p-value
Number of subjects, n	30	30	30	90	-
Number of teeth, n	60	60	60	180	-
Age (years), mean $\pm$ SD	$24.9 \pm 3.8$	$29.7 \pm 4.9$	$34.8 \pm 5.6$	$29.8 \pm 6.4$	<0.001
Female, n (%)	15 (50.0)	14 (46.7)	16 (53.3)	45 (50.0)	0.89
Male, n (%)	15 (50.0)	16 (53.3)	14 (46.7)	45 (50.0)	0.89

Baseline characteristics of the study sample according to occlusal wear stage. Data are presented as mean  $\pm$  standard deviation (SD) or number (%), as appropriate

### ***Intraindividual contralateral morphological similarity according to wear stage***

Contralateral morphological similarity decreased progressively with increasing occlusal wear. The lowest mean Procrustes distance and occlusal asymmetry index were recorded in wear stage 1, whereas the highest values were observed in wear stage 3. A similar trend was found for centroid size difference, indicating that both shape and size discrepancy increased with advancing wear. Regional analysis showed greater deviation in the palatal cuspal area than in the buccal cuspal area, with the highest mean values recorded in the advanced wear group. Progressive occlusal wear was associated with reduced intraindividual contralateral morphological similarity. The main morphometric parameters are summarized in Table 2.

**Table 2.** Intraindividual contralateral morphological similarity according to occlusal wear stage

Parameter	Wear Stage 1 (n = 30)	Wear Stage 2 (n = 30)	Wear Stage 3 (n = 30)	p-value
<b>Procrustes distance, mean ± SD</b>	0.021 ± 0.006	0.029 ± 0.008	0.038 ± 0.010	<0.001
<b>Centroid size difference, mean ± SD</b>	0.84 ± 0.27	1.12 ± 0.34	1.46 ± 0.41	<0.001
<b>Occlusal asymmetry index, mean ± SD</b>	0.18 ± 0.05	0.26 ± 0.07	0.35 ± 0.09	<0.001
<b>Palatal cusp deviation, mean ± SD</b>	0.31 ± 0.09	0.43 ± 0.12	0.58 ± 0.15	<0.001
<b>Buccal cusp deviation, mean ± SD</b>	0.24 ± 0.07	0.33 ± 0.09	0.44 ± 0.11	<0.001

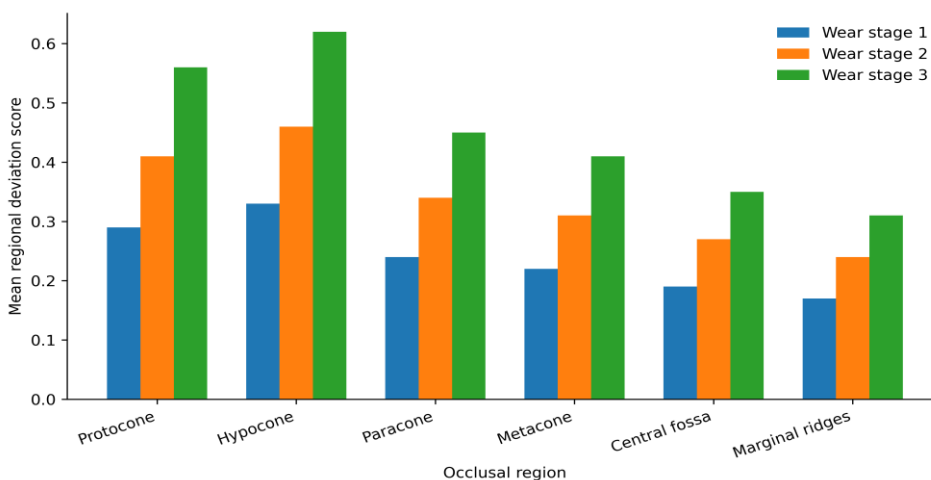
***Regional occlusal morphological variation and the effect of tooth wear***

Regional occlusal variation increased progressively with the severity of tooth wear. The highest deviation scores were observed in the palatal cuspal regions, particularly at the level of the hypocone and protocone, whereas the central fossa and marginal ridges showed lower levels of variation across all groups. Wear stage 3 consistently demonstrated the greatest regional displacement values, indicating more pronounced loss of contralateral occlusal symmetry in advanced wear. The regional morphometric findings are summarized in Table 3, and the distribution of regional deviation scores across wear stages is presented in Figure 1.

**Table 3.** Regional occlusal morphological variation according to occlusal wear stage

Occlusal Region	Wear Stage 1 (n = 30)	Wear Stage 2 (n = 30)	Wear Stage 3 (n = 30)	p-value
<b>Protocone region, mean ± SD</b>	0.29 ± 0.08	0.41 ± 0.11	0.56 ± 0.14	<0.001
<b>Hypocone region, mean ± SD</b>	0.33 ± 0.09	0.46 ± 0.12	0.62 ± 0.16	<0.001
<b>Paracone region, mean ± SD</b>	0.24 ± 0.07	0.34 ± 0.09	0.45 ± 0.12	<0.001
<b>Metacone region, mean ± SD</b>	0.22 ± 0.06	0.31 ± 0.08	0.41 ± 0.10	<0.001
<b>Central fossa, mean ± SD</b>	0.19 ± 0.05	0.27 ± 0.07	0.35 ± 0.09	<0.001
<b>Marginal ridges, mean ± SD</b>	0.17 ± 0.05	0.24 ± 0.06	0.31 ± 0.08	<0.001

The distribution of regional deviation scores across occlusal wear stages is shown in Figure 1.



**Figure 1.** Regional occlusal morphological variation according to occlusal wear stage in contralateral permanent upper first molars

## Discussion

Our study investigated the intraindividual contralateral occlusal morphological similarity of permanent upper first molars across different stages of tooth wear using a three-dimensional geometric morphometric approach. The main findings were that contralateral similarity decreased progressively as occlusal wear advanced, that both global and regional morphometric discrepancies increased from wear stage 1 to wear stage 3, and that the greatest regional deviations were located in the palatal cuspal area, particularly at the level of the hypocone and protocone. These observations support the concept that tooth wear does not merely reduce crown height but progressively modifies the spatial configuration of the occlusal surface and weakens contralateral morphological correspondence.

Our results are consistent with the idea that molar morphology is functionally structured and that occlusal anatomy reflects the interaction between original crown design and progressive wear. Previous work has shown that enamel thickness is not uniformly distributed across the occlusal surface and that its relationship with macrowear varies according to masticatory phases, suggesting that wear-related remodeling follows biologically patterned trajectories rather than random tissue loss [1]. This helps explain why our regional analysis did not show uniform displacement across the crown, but rather a concentration of variation in selected occlusal regions. Such a finding also aligns with evidence indicating that crown morphology and wear behavior are tightly connected to functional loading and masticatory mechanics [7,10].

Our study also supports the broader view that molar morphology retains an underlying developmental organization even when exposed to progressive wear. Genetic studies on intercuspal dimensions and molar form have demonstrated that crown structure is under substantial hereditary control, with measurable contributions of shared developmental pathways and pleiotropic effects [4,18]. This is relevant because contralateral teeth originate within the same individual developmental environment and are therefore expected to preserve a relatively high degree of symmetry. The progressive increase in Procrustes distance, centroid size

discrepancy, and occlusal asymmetry index observed in our results suggests that tooth wear acts as a modifying process superimposed on this biologically constrained symmetry, rather than replacing it entirely.

The regional predominance of deviation in the palatal cuspal area deserves particular attention. In our material, the hypocone and protocone showed the highest displacement values across all wear stages, with the greatest differences observed in advanced wear. This distribution is biologically plausible because the occlusal topography of maxillary first molars is not functionally homogeneous. Variability in enamel thickness, cusp contribution to mastication, and occlusal contact dynamics may all influence the regional expression of wear [1,8,20]. In addition, studies of occlusion and chewing behavior suggest that contact patterns are closely associated with the way occlusal surfaces evolve, which may further accentuate regional differences in shape preservation between contralateral teeth [19].

Another important aspect of our findings is the methodological value of geometric morphometrics for detecting subtle asymmetry. Traditional odontometric approaches are useful for linear comparisons, but they may underestimate localized shape divergence when surface remodeling is complex. In contrast, geometric morphometric methods allow simultaneous evaluation of global form and regional displacement through landmark-based spatial analysis [16,17]. This is particularly important in the context of tooth wear, where the biologically meaningful changes are not always captured by simple dimensional reduction. Our results confirm that even when bilateral molars appear clinically similar, measurable three-dimensional asymmetry may already be present and may increase significantly with wear progression. Recent applications of geometric morphometrics to fluctuating asymmetry also support the sensitivity of this approach in the assessment of fine-scale morphological divergence [9].

Our study may also have clinical implications. In restorative dentistry and prosthodontics, the contralateral tooth is often considered a practical anatomic reference when reconstructing occlusal morphology. However, our findings indicate that this assumption should be applied cautiously in the presence of moderate or advanced tooth wear. As wear increases, contralateral molars become less morphologically similar, especially in cusp-dominant regions that are critical for occlusal function. This observation is relevant in light of contemporary restorative principles, where accurate occlusal design is essential for functional integration and long-term stability [11]. It also supports the need for individualized digital assessment rather than direct contralateral mirroring in worn dentitions.

At a broader biological level, our results fit within the growing literature showing that dental morphology remains highly informative even in altered or worn dentitions. Dental shape has long been used to infer developmental, taxonomic, and population-level relationships [12,13], and our findings add to this perspective by showing that wear-related remodeling follows structured and quantifiable pathways. Rather than obscuring morphology completely, wear appears to redistribute it, preserving some regions more than others and progressively increasing asymmetry between paired elements.

Several limitations should be acknowledged. Our analysis was restricted to permanent upper first molars and, therefore, cannot be generalized directly to other tooth classes. The use of a three-stage wear classification, while practical and reproducible, inevitably simplifies a biologically continuous process. In addition, although digital models allow robust surface analysis, the study did not incorporate enamel–dentin junction data or direct functional loading measurements. Finally, despite the balanced sample design, the observational nature of the

material does not allow causal inferences regarding the biomechanical determinants of wear-related asymmetry.

Despite these limitations, our study has important strengths. It used a balanced sample, a structured wear-stage design, and a three-dimensional geometric morphometric framework capable of quantifying both global and regional variation. It also addressed a clinically and biologically relevant question: whether contralateral upper first molars remain reliable morphological counterparts as tooth wear progresses. Our results indicate that contralateral similarity decreases systematically with wear, and that palatal cuspal regions are particularly affected.

Overall, our study suggests that occlusal wear should be regarded not only as a surface loss phenomenon but also as a progressive modifier of bilateral morphological symmetry. This perspective may be relevant for future morphometric research, functional interpretation of worn dentitions, and digitally guided restorative reconstruction.

## Conclusions

Our study showed that intraindividual contralateral occlusal similarity of permanent upper first molars decreased progressively with increasing tooth wear. Both global morphometric parameters and regional deviation scores demonstrated a consistent trend from wear stage 1 to wear stage 3, indicating that wear affects not only crown height but also three-dimensional occlusal configuration. The greatest regional variation was identified in the palatal cusp area, particularly at the level of the hypocone and protocone. These findings support the view that occlusal wear progressively reduces bilateral morphological correspondence in upper first molars. Our study also suggests that contralateral upper first molars should not be considered fully interchangeable morphological templates in the presence of moderate or advanced occlusal wear. Although bilateral similarity remains relatively high in minimally worn dentitions, progressive wear is associated with increasing asymmetry and region-specific remodeling, especially in functionally relevant cuspal areas. These observations are clinically relevant for digital reconstruction, restorative planning, and prosthodontic design, where contralateral mirroring is often used as a reference strategy. Further studies integrating functional loading, enamel distribution, and larger digital datasets are needed to better define the biological mechanisms and clinical implications of wear-related occlusal morphological divergence.

## References

1. Oxilia G., Zaniboni M., Bortolini E., Menghi Sartorio J.C., Bernardini F., Tuniz C., Di Domenico G., Tresić Pavičić D., Los D., Radović S., et al.: *Enamel thickness per masticatory phases (ETMP): A new approach to assess the relationship between macrowear and enamel thickness in the human lower first molar*. **J. Archaeol. Sci.** 2023. 153,105776. doi: 10.1016/j.jas.2023.105776.
2. Romandini M., Oxilia G., Bortolini E., Peyrégne S., Delpiano D., Nava A., Panetta D., Di Domenico G., Martini P., Arrighi S., et al.: *A late Neanderthal tooth from northeastern Italy*. **J. Hum. Evol.** 2020. 147,102867. doi: 10.1016/j.jhevol.2020.102867.

3. Vazzana A., Scalise L.M., Traversari M., Figus C., Apicella S.A., Buti L., Oxilia G., Sorrentino R., Pellegrini S., Matteucci C., et al.: *A multianalytic investigation of weapon-related injuries in a Late Antiquity necropolis, Mutina, Italy*. **J. Archaeol. Sci. Rep.** 2018. 17,550–559. doi: 10.1016/j.jasrep.2017.12.009.
4. Townsend G., Richards L., Hughes T: *Molar intercuspal dimensions: Genetic input to phenotypic variation*. **J. Dent. Res.** 2003. 82,350–355. doi: 10.1177/154405910308200505.
5. Johnsen G.F., Haugen H.J., Nogueira L.P., Sevgi U., Jimenez A.M., DeLuca J.T., Mancuso R., Piasecki L: *Assessment of the root canal similarity in contralateral mandibular incisors*. **Int. Dent. J.** 2023. 73,71–78. doi: 10.1016/j.identj.2022.04.003.
6. Dandache G., Aksoy U., Ozel M.B., Orhan K: *Anatomic comparison of contralateral maxillary second molars using high-resolution micro-CT*. **Symmetry**. 2023. 15,420. doi: 10.3390/sym15020420.
7. Oxilia G., Bortolini E., Martini S., Papini A., Boggioni M., Buti L., Benazzi S: *The physiological linkage between molar inclination and dental macrowear pattern*. **Am. J. Phys. Anthropol.** 2018. 166,941–951. doi: 10.1002/ajpa.23476.
8. Morita W., Yano W., Nagaoka T., Abe M., Ohshima H., Nakatsukasa M: *Patterns of morphological variation in enamel–dentin junction and outer enamel surface of human molars*. **J. Anat.** 2014. 224,669–680. doi: 10.1111/joa.12180.
9. Wigley B., Stillman E., Craig-Atkins E: *Taking shape: A new geometric morphometric approach to quantifying dental fluctuating asymmetry and its application to the evaluation of developmental stress*. **Archaeometry**. 2024. 66,1399–1423. doi: 10.1111/arc.12973.
10. Kullmer O., Benazzi S., Fiorenza L., Schulz D., Bacso S., Winzen O: *Occlusal Fingerprint Analysis (OFA)—Quantification of tooth wear pattern*. **Am. J. Phys. Anthropol.** 2009. 139,600–605. doi: 10.1002/ajpa.21086.
11. Cato J: *Book review: Functional Occlusion in Restorative Dentistry and Prosthodontics*. **Br Dent J.** 2016. 220,225. doi: 10.1038/sj.bdj.2016.170.
12. Rathmann H., Vizzari M.T., Beier J., Bailey S.E., Ghirotto S., Harvati K: *Human population dynamics in Upper Paleolithic Europe inferred from fossil dental phenotypes*. **Sci. Adv.** 2024. 10,eadn8129. doi: 10.1126/sciadv.adn8129.
13. Irish J.D., Guatelli-Steinberg D., Legge S.S., de Ruiter D.J., Berger L.R: *Dental morphology and the phylogenetic “place” of Australopithecus sediba*. **Science**. 2013. 340,1233062. doi: 10.1126/science.1233062.
14. Hlusko L.J., Suwa G., Kono R.T., Mahaney M.C: *Genetics and the evolution of primate enamel thickness: A baboon model*. **Am. J. Phys. Anthropol.** 2004. 124,223–233. doi: 10.1002/ajpa.10353.
15. Kurita H. *Temporomandibular joint skeletal morphology in children and adults*. **J. Postgrad. Med.** 2008. 54:180. doi: 10.4103/0022-3859.41797.
16. Mitteroecker P., Gunz P: *Advances in geometric morphometrics*. **Evol. Biol.** 2009. 36,235–247. doi: 10.1007/s11692-009-9055-x.
17. Gunz P., Mitteroecker P: *Semilandmarks: A method for quantifying curves and surfaces*. **Hystrix Ital. J. Mammal.** 2013. 24,103–109. doi: 10.4404/hystrix-24.1-6298.
18. Paul K.S., Stojanowski C.M., Hughes T., Brook A.H., Townsend G.C: *Genetic correlation, pleiotropy, and molar morphology in a longitudinal sample of Australian twins and families*. **Genes**. 2022. 13,996. doi: 10.3390/genes13060996.

19. Silvester C.M., Kullmer O., Hillson S: *A dental revolution: The association between occlusion and chewing behaviour*. **PLoS ONE**. 2021. 16,e0261404. doi: 10.1371/journal.pone.0261404.
  20. Gaboutchian A.V., Knyaz V.A., Maschenko E.N., Dac L.X., Maksimov A.A., Emelyanov A.V., Korost D.V., Stepanov N.V.: *Measuring dental enamel thickness: Morphological and functional relevance of topographic mapping*. **J. Imaging**. 2023. 9,127. doi: 10.3390/jimaging9070127.
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*Received: November 14, 2025*

*Accepted: February 19, 2026*