DOI: 10.4274/TurkJOrthod.2025.2025.36

TURKISH JOURNAL OF
ORTHODONTICS

Original Article

3-Dimensional Evaluation of Enamel Thickness to Guide Orthodontic Interproximal Reduction: A CBCT-Based Study Across Gender and Ethnicity

Ezgi Cansu Fırıncıoğulları[1], Aslıhan Ertan Erdinç[2], Sercan Akyalçın[3]

[1]University of Nebraska Medical Center, Department of Growth and Development, Omaha, NE, USA
[2]Ege University Faculty of Dentistry, İzmir, Türkiye
[3]Harvard School of Dental Medicine, Department of Orthodontics, Boston, USA

Cite this article as: Fırıncıoğulları EC, Ertan Erdinç A, Akyalçın S. 3-dimensional evaluation of enamel thickness to guide orthodontic interproximal reduction: a CBCT-based study across gender and ethnicity. *Turk J Orthod.* 2025; 38(2): 89-96

Main Points

- Enamel thickness varies significantly between Caucasian and Somalian populations, regardless of tooth location(anterior/posterior, distal/mesial).
- Gender does not appear to influence enamel thickness across different ethnic backgrounds.
- In the posterior regions of both arches, distal surfaces generally have greater enamel thickness than mesial surfaces, making them safer for interproximal reduction.

ABSTRACT

Objective: This study aimed to explore variations in enamel thickness to provide guidelines for optimal interproximal enamel reduction in an untreated population using cone-beam computed tomography (CBCT).

Methods: CBCT scans of 100 orthodontic patients (51 Caucasian, 49 patients of Somalian descent; aged (12-18) were analyzed retrospectively. Enamel thickness was measured at the mesial and distal contact points of teeth from the second molar to the central incisor in both the maxillary and mandibular arches. Linear mixed models were employed to assess the effects of ethnicity, gender, anterior-posterior region, and mesial-distal proximal surfaces on enamel thickness. Fixed effects were estimated using the Kenward-Roger method, and a random intercept with an unstructured covariance matrix was included to account for within-subject variability. Ethnicity-specific residual variances were also modeled. Statistical significance was set at p<0.05.

Results: Enamel thickness varied significantly between Caucasians and Somalians in both the maxilla and mandible (p<0.001), with greater thickness observed in Caucasians. Gender-related differences were minimal; however, in the maxilla, distal surfaces of posterior teeth had greater enamel thickness in females compared to males (p=0.0478). Enamel thickness was consistently greater on distal surfaces of posterior teeth (p<0.001), while no significant differences were observed between mesial and distal surfaces in anterior teeth (p>0.05).

Conclusion: Posterior teeth, particularly distal proximal surfaces of premolars and molars hold a great potential for enamel reduction, offering clinicians the most optimal site in orthodontic interventions.

Keywords: Enamel thickness, interproximal reduction, cone-beam computed tomography, orthodontics, gender differences, ethnic variations

Corresponding author: Ezgi Cansu Fırıncıoğulları, **e-mail:** ezgicansu.erul@gmail.com
Received: February 26, 2025 **Accepted:** April 07, 2025 **Publication Date:** July 02, 2025

Copyright© 2025 The Author. Published by Galenos Publishing House on behalf of Turkish Orthodontic Society.
This is an open access article under the Creative Commons AttributionNonCommercial 4.0 International (CC BY-NC 4.0) License.

INTRODUCTION

A critical aspect of orthodontic treatment planning is accurately identifying the direction and magnitude of dental movements required within each arch quadrant. In many instances, achieving the desired dental movements necessitates the creation of adequate space to address the malocclusion. One of the most widely utilized techniques for gaining additional space is interproximal enamel reduction (IPR) which has been gaining popularity in clinical practice, particularly through the advocates of aligners and non-extraction treatment.[1] This method mimics the natural physiological process of interdental attrition, which occurs as part of normal aging.[2] Many practitioners rely on the strategic use of IPR to manage mild to moderate tooth-size discrepancies without the need for extractions.[3] Therefore, accurate assessment of enamel thickness across different sections is of critical importance in optimizing treatment outcomes.

The expanding body of literature has explored enamel thickness at interproximal surfaces and, the extent of how much IPR could safely be performed depends mostly on the enamel thickness and other patient-related factors.[4,5] According to Frindel,[6] the maximum recommended reduction is 0.3 mm for upper incisors, 0.2 mm for lower incisors, and 0.6 mm for both upper and lower posterior teeth. Sheridan and Ledoux[7] further suggested that the total space gained through IPR for the premolar region could reach up to 6.4 mm. Additionally, it has been proposed that up to 50% of interproximal enamel can be safely removed with IPR.[8]

The increasing popularity of IPR is closely related to the growing demand for orthodontic treatment among adults.[9] Challenges encountered in space closure for adult patients, the risk of reopening extraction spaces after extraction treatments, and the ability of IPR to provide just enough space by removing only the required enamel[10] make it an attractive alternative for cases with mild to moderate crowding (4-8 mm).[11] However, IPR is not used exclusively for space creation. Other common applications include resolving black triangles, managing Bolton discrepancies, and more.[12,13] Nearly every orthodontic patient has the potential to benefit from IPR. Therefore, orthodontists require evidence-based data on how the amount of IPR varies based on gender, mesiodistal surface, anterior-posterior region, and racial differences.

Recently, patient-centered treatment principles have led to the limitation of extraction-based treatments to severe malocclusion cases. In simpler cases, faster and less invasive treatment options have become more popular.[10] Consequently, methods like distalization, expansion, and IPR have become more widely adopted, with increasing attention in the literature. According to an epidemiological study in the United States, severe crowding (≥7 mm), which may necessitate extractions, is observed in only 16.8% of the adult population.[14] From a clinical perspective, the findings in the literature indicate that IPR could provide more opportunity for non-extraction treatment in individuals with treatment objectives centering around no major change for the incisor position.

Given the clinical relevance of enamel thickness variations in IPR applications, our study aimed to quantify enamel thickness using cone-beam computed tomography (CBCT) to provide the clinicians with further evidence and guidance across genders, ethnic origins, groups and proximal surfaces of teeth. Although the body of evidence suggested that IPR within recognized limits would have no iatrogenic harm to the teeth and supporting structures,[15] the current study investigated the effects of multiple factors in enamel thickness variation. We aim to provide further supplementary data to the clinicians for optimizing their treatment decisions. The null hypothesis was that enamel thickness would not reveal any differences between different ethnic groups, sex, location and sites of teeth.

METHODS

The study was reviewed and approved by the Institutional Review Board (Tufts University #2018-11181). The CBCT records of 100 orthodontic patients (n=51 Caucasian and n=49 Somalian) were uploaded to *InVivo* (Anatomage, San Jose, CA) for volume rendering and sectioning. Axial and frontal slices of the maxillary and mandibular dentition, extending from the second molar to the contralateral second molar, were obtained for measurement purposes. Enamel thickness was assessed at the mesial and distal proximal surfaces of each tooth at the contact points within each quadrant. The mean enamel thickness was then calculated for each tooth. The inclusion criteria for the evaluation consisted of an age range of 12-18, fully erupted first and second molars, absence of any wear, absence of grinding or clenching. Patients with a history of prior orthodontic treatment, interproximal restorations, any kind of missing teeth or agenesis, tooth shape and size anomalies (macrodontia, peg laterals, twinning, etc.), craniofacial anomalies, necessitated exclusion from the study.

CBCT images were opened in *InVivo* (Anatomage, San Jose, CA). Axial (Figure 1a) and frontal (Figure 1b) slices of maxillary and mandibular teeth from the second molar to the central incisor were generated for the measurements. The thickness of the enamel on the proximal surfaces was measured directly from the mesial and distal contact points on the shortest line possible to the dentin and enamel junction perpendicular to the long axis of the tooth.

For the purposes of the study, central incisors, lateral incisors, and canines were grouped as the anterior teeth, while premolars, first molars, and second molars were labeled as the posterior teeth. A linear mixed model (LMM) was employed to evaluate the effects of ethnicity (Groups: Caucasian vs. Somalian), gender (male vs. female), tooth position [anterior vs. posterior (ant_post)], and surface [mesial vs. distal (DM)] on enamel thickness.

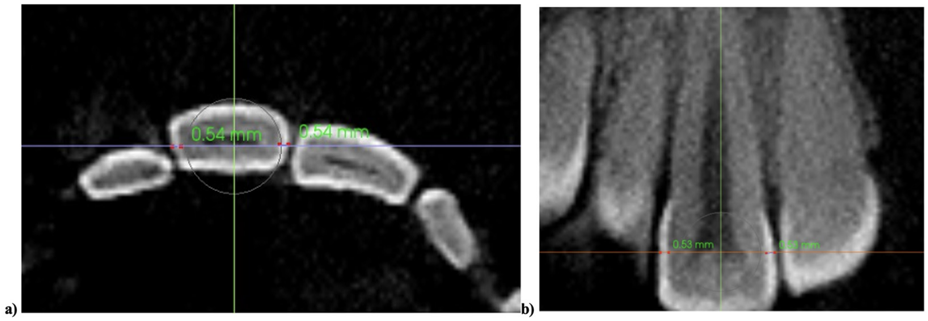

Figure 1. Axial and frontal view of a maxillary right central incisor. Enamel thickness measurements are made on mesial and distal proximal aspects at the contact point

Statistical Analysis

The enamel thickness was used as the dependent variable to achieve a normalized data distribution. The model included all main effects and their interactions. Fixed effects were estimated using the Kenward-Roger method to adjust degrees of freedom. A random intercept was included to account for within-subject variability, utilizing an unstructured covariance matrix. Additionally, ethnicity-specific residual variances were incorporated to account for heterogeneity at the ethnicity level.

In analyzing the results for the mandible, only the DM × ant_post interaction was significant (Table 1), while for the maxilla, gender × ant_post and DM × ant_post interactions were significant (Table 2). Interaction analyses were conducted using least squares mean differences to explore the effects further. The results of the least squares mean differences were used to evaluate specific subgroup interactions and to identify differences within the data that might not be apparent in the main effects analysis. For each comparison, the Tukey-Kramer adjustment was applied to control for multiple testing and provide adjusted p-values.

Statistical significance was set at p<0.05. LMMs were performed using SAS software (version 9.3; procedure: PROC MIXED; SAS Institute, Cary, NC, USA). Graphics were generated using R software (version 4.0.5; package: ggplot2, R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

In the mandible, a significant difference in mean enamel thickness was found between two groups (Caucasians and Somalians) (p<0.001; Table 1). This difference was not affected by gender, anterior-posterior region, or DM surfaces. Similarly, no significant difference in enamel thickness was observed between genders (p=0.2898; Table 2, Figure 2), (Table 1).

The only statistically significant interaction was between DM surface and anterior-posterior region (p=0.0148).

In the posterior region, the distal surface exhibited a higher mean enamel thickness compared to the mesial surface (adjusted p<0.001). Conversely, no significant differences between surfaces were observed in the anterior region (adjusted p=0.7644). Both distal and mesial surfaces demonstrated a higher mean enamel thickness in the posterior region compared to the anterior region (Table 3, for both, adjusted p<0.001).

Table 1. Results of mixed-effects model of mandible: type III fixed effects

Test statistics	Den DF	F value		p-value
Groups	1	96.4	18.37	<0.0001
Gender	1	96.4	1.13	0.2898
Groups*Gender	1	96.4	0.25	0.6148
DM	1	1280	15.31	<0.0001
Groups*DM	1	1280	2.45	0.1179
Gender*DM	1	1280	0	0.9910
Groups*Gender*DM	1	1280	0.01	0.9283
ant_post	1	1280	482.28	<0.0001
Groups*ant_post	1	1280	1.77	0.1839
Gender*ant_post	1	1280	0.09	0.7636
Groups*Gender*ant_post	1	1280	0.09	0.7593
DM*ant_post	1	1280	5.96	0.0148
Groups*DM*ant_post	1	1280	0.14	0.7067
Gender*DM*ant_post	1	1280	0	0.9849
Group*Gender*DM*ant_post	1	1280	0	0.9469

ant_post: anterior vs. posterior, DM: mesial vs. distal

In the maxilla, like findings in the mandible, a significant difference in mean enamel thickness was observed between two ethnic groups (p<0.001; Table 2, Figure 3). This difference was not influenced by gender, anterior-posterior region, or DM surfaces interactions between DM surface and anterior-posterior region, as well as between gender and anterior-posterior region, were statistically significant (p=0.004 and p=0.0478, respectively; Table 2).

Consistent with findings in the mandible, the posterior region's distal surface demonstrated a higher mean enamel thickness compared to the mesial surface (adjusted p<0.001). In contrast, no significant difference was observed between surfaces in the anterior region (adjusted p=0.8180).

No significant differences were found between genders in either region (anterior: p=0.6683; posterior: p=0.9990). Among females, the mean enamel thickness in the posterior region was higher on the distal surface, and among males, the mean enamel thickness in the anterior region was higher on the mesial surface; however, these differences were not statistically significant (Table 3 and 4, adjusted p=0.2487 and adjusted p=0.1872, respectively).

DISCUSSION

IPR is an effective method orthodontists use to create space by reducing the mesiodistal dimension of teeth. This procedure involves the removal of enamel material from the proximal surfaces of teeth, which can be performed using manual or automatic systems.[10] Despite various opinions in the literature about the maximum amount of IPR, individual differences in enamel thickness have been emphasized.[5,16-18] Understanding the variations in enamel thickness across different genders, ethnic backgrounds, tooth surfaces, and regions is critical for performing safe and effective IPR in orthodontic treatment. Despite the growing use of IPR, especially with the rise of clear aligner therapy, there remains limited evidence-based guidance tailored to individual patient characteristics. This study aimed to provide clinically relevant enamel thickness data using CBCT imaging to support more personalized and informed IPR protocols.

The literature contains diverse perspectives on the amount of space that can be gained with IPR. Recent studies highlight the importance of determining enamel thickness before the procedure, as it varies among individuals.[18,19] This study is distinguished by its specific age range selection, which was designed to minimize potential variations in interdental attrition across different age groups, thereby enhancing the reliability of enamel thickness comparisons. It is well-documented that interdental attrition occurs with age, transforming contact points into contact surfaces.[20] Attrition related changes could mean that enamel thickness and tooth width in the same individual differ at different ages. Therefore, our study measured only enamel thickness rather than overall tooth dimensions. Although there is a high correlation between tooth size and enamel thickness,[18,21] focusing on enamel thickness alone allowed for the acquisition of precise mesial and distal enamel thickness.

Results of this research showed that, similar to the findings of Moss and Moss-Salentijn,[22] the enamel thickness of mandibular

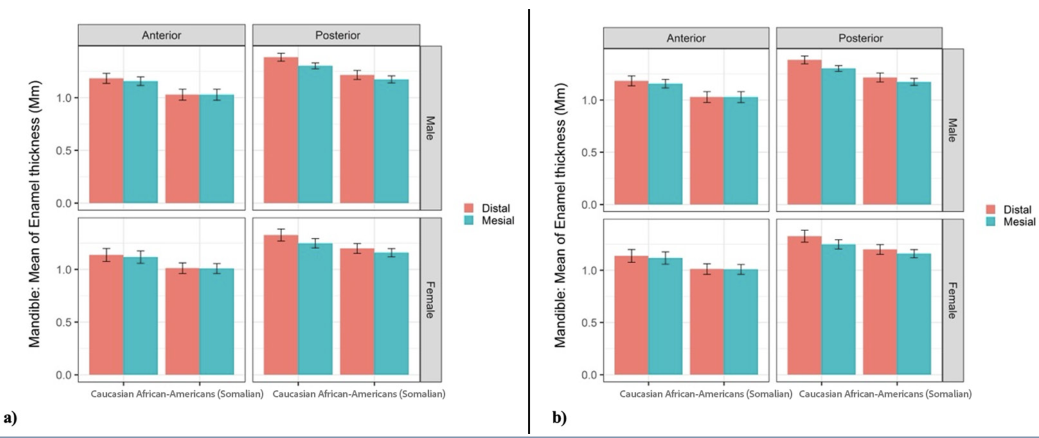

Figure 2. Mean enamel tickness and mean enamel tickness in log transformation of mandibular anterior and posterior teeth
Note: The Somalian group does not represent the full diversity of individuals categorized as African American.

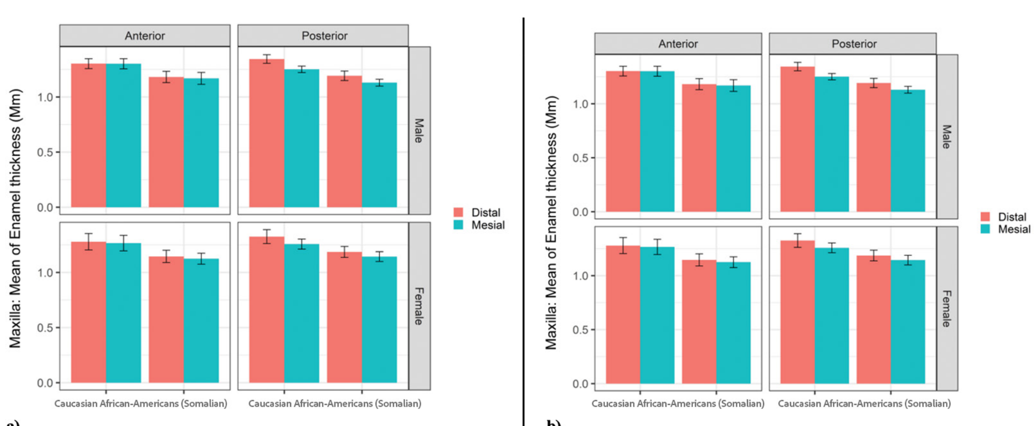

Figure 3. Mean enamel tickness and mean enamel tickness in log transformation of maxillary anterior and posterior teeth

canines in males was greater than that in females in both groups. Enamel thicknesses in the maxillary posterior region did not change between genders, consistent with the findings of Stroud et al.[5] Mandibular lateral incisors demonstrated greater enamel thickness compared to mandibular central incisors like Hall et al.'s[18] results. In line with findings reported in the literature, which indicate that enamel thickness is greater on distal surfaces than on mesial surfaces, this study showed similar findings exclusively for maxillary and mandibular posterior teeth and upper central incisors.[17] However, no significant differences were observed between mesial and distal surfaces in anterior teeth similar to Sarig et al.[10] and Konstantinidou et al.[23] The variations in these[24] findings can be attributed to differences in the methodologies employed, as Sarig et al.[10] study. Enamel thickness was measured at the mesial and distal contact points in this study and the referenced work. In contrast, Macha et al.[25] and Fernandes et al.[26] focused solely on the maximum enamel thickness, while Stroud et al.[4,5] assessed enamel thickness using radiographic techniques. Consistent with previous studies,[4,5,18] no gender-related differences in enamel thickness were observed in the mandibular anterior and posterior teeth. In the maxilla, no differences in enamel thickness were found between genders in anterior teeth. In contrast, in posterior teeth, the mean enamel thickness on distal surfaces was greater in females than in males.

The locations where enamel thickness was measured vary significantly across studies. Some measured the enamel thickness at mesial and distal contact areas, while others measured the greatest enamel thickness.[12] In this study, measurements were taken directly at the contact points on CBCT scans, as IPR is typically performed clinically starting from the contact points. This choice ensures the amount of enamel removed is calculated precisely at these locations, rather than at the areas of thickest enamel. A meta-analysis in 2021 recommended using 3D evaluation methods, for assessing enamel thickness to guide clinicians.[12] This study used CBCT instead of 2D evaluation methods reducing potential errors from magnification and angles. The right and left sides were not evaluated separately, as the literature indicates that the symmetry of the right and left teeth is nearly perfect, with a very high correlation.[12]

Clinicians use IPR less in the posterior region due to its distance from the anterior region, despite evidence indicating a progressive increase in enamel thickness from anterior to posterior teeth.[16] The findings of this study have important clinical implications, particularly for orthodontic treatment planning involving IPR. The observed variations in enamel thickness across ethnicities and genders highlight the necessity for individualized treatment protocols. For instance, the consistently greater enamel thickness observed in Caucasians compared to Somalians and the thicker enamel found in posterior teeth, particularly on distal surfaces irrespective of ethnicity, indicate that Caucasians and distal surfaces of posterior teeth may tolerate more aggressive enamel reduction without compromising dental integrity. Clinicians can use this evidence to optimize IPR procedures, minimizing risks while maximizing space creation in cases of mild to moderate

Table 2. Results of mixed-effects model of maxilla: type III fixed effects

Test statistics	Den DF	F value	p-value
Groups	96.7	17.29	<0.0001
Gender	96.7	0.44	0.5086
Groups*Gender	96.7	0	0.9836
DM	1255	17.67	<0.0001
Groups*DM	1255	0.07	0.7985
Gender*DM	1255	0.21	0.6458
Groups*Gender*DM	1255	0.01	0.9239
ant_post	1255	1.57	0.2110
Groups*ant_post	1255	0.01	0.9144
Gender*ant_post	1255	3.92	0.0478
Groups*Gender*ant_post	1255	0.3	0.5846
DM*ant_post	1255	8.3	0.0040
Groups*DM*ant_post	1255	0.73	0.3943
Gender*DM*ant_post	1255	0.7	0.4030
Groups*Gender*DM*ant_post	1255	0.04	0.8368

Table 3. Mean±standard deviation of enamel thickness

			Caucasian		Somalian	
			Distal	Mesial	Distal	Mesial
Maxilla	Male	Anterior	1.30±0.23	1.30±0.24	1.18±0.23	1.17±0.24
		Posterior	1.34±0.23	1.25±0.17	1.19±0.22	1.13±0.16
	Female	Anterior	1.28±0.27	1.27±0.25	1.15±0.23	1.12±0.21
		Posterior	1.33±0.26	1.26±0.19	1.19±0.24	1.14±0.22
Mandible	Male	Anterior	1.18±0.24	1.16±0.21	1.03±0.23	1.03±0.23
		Posterior	1.38±0.22	1.30±0.16	1.22±0.22	1.17±0.17
	Female	Anterior	1.14±0.22	1.12±0.21	1.01±0.21	1.01±0.20
		Posterior	1.33±0.24	1.25±0.18	1.20±0.22	1.16±0.19

Table 4. Minimum, maximum, mean and standard deviation of enamel thickness (mm) for each tooth on mesial and distal surfaces, categorized by ethnicity, gender, and arch (maxilla and mandible)

		Caucasian n=51 (Female n=17, Male n=34)								Somalian n=49 (Female n=23, Male n=26)							
		Maxillary				Mandibular				Maxillary				Mandibular			
Gender	Tooth no and surface	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation
Male	7D	1.12	1.93	1.5841	0.20440	1.15	2.17	1.5815	0.22600	1.21	1.86	1.4037	0.18321	1.00	1.96	1.3765	0.20887
	7M	1.06	1.84	1.3456	0.18599	1.01	1.59	1.3443	0.13970	1.02	1.64	1.2138	0.13985	1.04	1.44	1.2171	0.11001
	6D	0.98	1.69	1.4015	0.16742	0.98	1.78	1.3878	0.18972	0.95	1.76	1.2271	0.21203	0.96	1.71	1.2435	0.21521
	6M	0.98	1.55	1.2969	0.15489	0.98	1.59	1.2859	0.15267	0.96	1.60	1.1717	0.15238	1.07	1.64	1.2165	0.15105
	5D	0.86	1.47	1.2088	0.14761	0.94	1.68	1.2574	0.14111	0.85	1.43	1.0658	0.13344	0.86	1.48	1.1242	0.16677
	5M	0.87	1.42	1.1643	0.12764	0.95	1.75	1.2715	0.17193	0.81	1.40	1.0617	0.13900	0.96	1.61	1.1260	0.16006
	4D	0.91	1.49	1.1834	0.13615	0.93	1.76	1.3103	0.18393	0.87	1.50	1.0719	0.16254	0.88	1.57	1.1202	0.19386
	4M	0.88	1.48	1.1966	0.15145	0.92	1.89	1.3059	0.18594	0.84	1.56	1.0715	0.16935	0.85	1.68	1.1352	0.22650
	3D	0.94	1.94	1.4419	0.22121	0.89	1.90	1.4272	0.23415	0.96	1.95	1.2404	0.25215	0.97	1.90	1.2165	0.25672
	3M	0.92	2.25	1.4369	0.26471	0.95	1.81	1.3587	0.20449	1.01	2.29	1.2573	0.29508	0.99	1.86	1.2183	0.26887
	2D	0.87	1.41	1.1482	0.14885	0.78	1.38	1.1012	0.14111	0.86	1.50	1.0831	0.15972	0.74	1.37	0.9519	0.15050
	2M	0.91	1.47	1.1626	0.16218	0.81	1.33	1.0776	0.13237	0.87	1.55	1.0613	0.13155	0.75	1.35	0.9415	0.14236
	1D	0.99	1.89	1.3181	0.21289	0.81	1.26	1.0235	0.10294	0.98	1.86	1.2221	0.23933	0.75	1.36	0.9185	0.13875
	1M	0.92	1.82	1.3046	0.18987	0.82	1.26	1.0346	0.10536	0.93	1.86	1.1888	0.22641	0.76	1.36	0.9260	0.13548
Female	7D	1.20	1.98	1.5665	0.25136	1.19	1.87	1.5268	0.22461	1.15	1.91	1.4180	0.20013	1.07	1.92	1.3833	0.21062
	7M	1.09	1.65	1.3468	0.18240	1.14	1.67	1.3185	0.15253	0.94	1.85	1.2615	0.22707	0.94	1.60	1.2283	0.17115
	6D	1.11	1.83	1.4185	0.22775	1.00	1.69	1.3429	0.20627	0.93	1.77	1.2015	0.20907	0.92	1.62	1.1952	0.17500
	6M	0.99	1.83	1.3568	0.20599	1.00	1.57	1.2768	0.18760	0.95	1.82	1.1909	0.20268	0.92	1.63	1.1904	0.16952
	5D	1.00	1.40	1.1903	0.12626	0.84	1.45	1.2174	0.17131	0.90	1.61	1.0654	0.17848	0.85	1.71	1.1037	0.20844
	5M	0.95	1.37	1.1529	0.12804	0.90	1.45	1.2003	0.16139	0.86	1.58	1.0535	0.17877	0.87	1.69	1.1111	0.20353
	4D	0.95	1.48	1.1256	0.14121	0.84	1.56	1.2200	0.20943	0.90	1.62	1.0611	0.18314	0.85	1.66	1.1165	0.19556
	4M	0.97	1.40	1.1735	0.13121	0.87	1.58	1.1971	0.21022	0.86	1.63	1.0698	0.19729	0.86	1.69	1.1098	0.19911
	3D	1.06	2.04	1.4609	0.30462	1.02	1.66	1.3032	0.18892	0.86	1.77	1.1935	0.24838	0.87	1.87	1.1520	0.25017
	3M	1.02	2.04	1.4650	0.28432	1.01	1.74	1.2856	0.20830	0.97	1.69	1.1659	0.18434	0.84	1.63	1.1357	0.22219
	2D	0.82	1.34	1.1094	0.13882	0.79	1.55	1.0803	0.21385	0.79	1.51	1.0393	0.15917	0.76	1.35	0.9528	0.15756
	2M	0.89	1.29	1.1109	0.12492	0.81	1.31	1.0424	0.15025	0.78	1.43	1.0261	0.14687	0.77	1.26	0.9443	0.14319
	1D	0.99	1.62	1.2653	0.20390	0.80	1.38	1.0306	0.15579	0.92	1.92	1.2037	0.25190	0.79	1.24	0.9337	0.14499
	1M	0.98	1.61	1.2224	0.17748	0.79	1.31	1.0235	0.15622	0.92	1.75	1.1822	0.24434	0.76	1.32	0.9443	0.16390

D: Distal surface, M: Mesial surface, 7: Second molar, 6: First molar, 5: Second premolar, 4: First premolar, 3: Canine, 2: Lateral incisor, 1: Central incisor, 7D: Distal surface of second molar

crowding. Comparatively, this study aligns with prior research indicating significant regional and surface-specific differences in enamel thickness but provides additional granularity by incorporating ethnicity and gender as variables. Unlike earlier studies that focusing primarily on radiographic assessments or gross enamel thickness, this research utilized CBCT to achieve precise, localized measurements.

In addition to the main effects, a significant interaction between DM surface and anterior-posterior region was observed in both arches, indicating that surface-related differences in enamel thickness are influenced by the location of the tooth. Specifically, in the posterior region, distal surfaces consistently demonstrated greater enamel thickness than mesial surfaces, while no such difference was observed in the anterior region. This highlights the importance of considering both surface and region simultaneously in clinical decision-making. Moreover, a significant interaction between gender and anterior-posterior region was found in the maxilla. Although overall gender-related differences in enamel thickness were not statistically significant, this interaction suggests that the relationship between gender and enamel thickness may vary depending on the tooth region. Post-hoc comparisons did not reveal significant pairwise differences; however, the presence of the interaction indicates a pattern that may become more apparent with larger sample sizes and should be explored in future studies.

In this study, all individuals in the Somalian group were classified under the broader racial category of African American,[27] while the Caucasian group included individuals from a range of ethnic backgrounds.[28] Recognizing this, referring to the comparison solely as one between racial groups could lead to scientific inaccuracy. Rather, this study involved a comparison between a specific ethnic subgroup (Somalian) and a racially defined but ethnically heterogeneous group (Caucasian). This distinction is important, as it underscores the need for caution in generalizing the findings to broader populations. The Somalian group does not represent the full diversity of individuals categorized as African American, and the Caucasian group comprises participants from different ethnic origins. Therefore, clinicians and researchers should interpret these results with care, particularly when applying enamel thickness data across different ethnic subgroups within the same racial classification.

Schwartz[24] suggested that enamel thickness is related to occlusal function; areas subjected to greater occlusal forces tend to have thinner enamel. A limitation of this study is that the participant group represents a specific age range; without standardized criteria to compare or evaluate occlusal function. However, it is important to note that patients with significant occlusal or proximal attrition were excluded. Another limitation of the study is the potential disadvantages associated with the use of CBCT, primarily due to its high ionizing radiation dose. Although CBCT is considered the gold standard for evaluating structures, it is not appropriate for use at frequent intervals.[29,30] Furthermore, in studies aiming to assess enamel thickness, the prospective acquisition of CBCT scans solely for research purposes may raise ethical concerns. Therefore, when evaluating enamel thickness in human subjects using CBCT, the only ethically acceptable approach is to conduct a retrospective analysis of previously acquired CBCT data. Future research should expand these findings by exploring additional ethnic groups and broader age ranges to enhance generalizability. Moreover, longitudinal studies assessing the long-term impact of IPR on enamel health and patient outcomes are necessary to further validate its safety and efficacy. Such studies would provide clinicians robust, evidence-based guidelines for personalized orthodontic care.

CONCLUSION

Clinicians should be cautious when performing IPR across different ethnicities, such as Caucasian and Somalian populations, due to variations in enamel thickness that are independent of gender, anterior-posterior region, or DM surfaces. Enamel thickness was generally similar between genders across different ethnic groups. In the posterior region of both arches, clinicians may perform IPR more safely on the distal surface than on the mesial surface due to greater enamel thickness.

Ethics

Ethics Committee Approval: The study was reviewed and approved by the institutional review board (Tufts Univ. #2018-11181).

Informed Consent: The study was approved by the Institutional Review Board with an "Expedited" status, and therefore, no patient consent form was required.

Footnotes

Author Contributions: Concept - A.M.E., S.A.; Design - E.C.F., S.A.; Data Collection and/or Processing - E.C.F.; Analysis and/or Interpretation - A.M.E., S.A.; Literature Search - E.C.F., A.M.E., S.A.; Writing - E.C.F., A.M.E., S.A.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

1. Güleç Ergün P, Arman Özçırpıcı A, Atakan Kocabalkan A, Tunçer Nİ. Evaluation of the consistency of two interproximal reduction methods in clear aligner therapy: a preliminary study. Turk J Orthod. 2024;37(1):1-6. [CrossRef]
2. Begg P. Stone age man's dentition: With reference to anatomically correct occlusion, the etiology of malocclusion, and a technique for its treatment. *Am J Orthod*. 1954;40:298-312. [CrossRef]
3. Germeç D, Ugur Taner T. Ortodontide interproksimal mine aşındırması. *Turk J Orthod*. 2008;21(1):67-79. [CrossRef]
4. Stroud JL, Buschang PH, Goaz PW. Sexual dimorphism in mesiodistal dentin and enamel thickness. *Dentomaxillofac Radiol*. 1994;23(3):169-171. [CrossRef]
5. Stroud JL, English J, Buschang PH. Enamel thickness of the posterior dentition: its implications for nonextraction treatment. *Angle Orthod*. 1998;68(2):141-146. [CrossRef]
6. Frindel C. Clear thinking about interproximal stripping. *J Dentofacial Anom Orthod*. 2010;13(2):187-199. [CrossRef]
7. Sheridan JJ, Ledoux PM. Air-rotor stripping and proximal sealants. An SEM evaluation. *J Clin Orthod*. 1989;23(12):790-794. [CrossRef]
8. Sheridan JJ. Air-rotor stripping update. *J Clin Orthod*. 1987;21(11):781-788. [CrossRef]
9. Germeç D, Taner TU. Effects of extraction and nonextraction therapy with air-rotor stripping on facial esthetics in postadolescent borderline patients. *Am J Orthod Dentofacial Orthop*. 2008;133(4):539-549. [CrossRef]
10. Sarig R, Vardimon AD, Sussan C, et al. Pattern of maxillary and mandibular proximal enamel thickness at the contact area of the permanent dentition from first molar to first molar. *Am J Orthod Dentofacial Orthop*. 2015;147(4):435-444. [CrossRef]
11. Pindoria J, Fleming PS, Sharma PK. Inter-proximal enamel reduction in contemporary orthodontics. *Br Dent J*. 2016;221(12):757-763. [CrossRef]

12. Kailasam V, Rangarajan H, Easwaran HN, Muthu MS. Proximal enamel thickness of the permanent teeth: A systematic review and meta-analysis. *Am J Orthod Dentofacial Orthop.* 2021;160(6):793-804.e3. [CrossRef]

13. Fırıncıoğulları EC, Erdinç AM. Interproximal enamel reduction (stripping) techniques in orthodontic treatment. *Int Arch Dent Sci.* 2023;44(2):173-179. [CrossRef]

14. Buschang PH, Shulman JD. Incisor crowding in untreated persons 15-50 years of age: United States, 1988-1994. *Angle Orthod*. 2003;73(5):502-508. [CrossRef]

15. Zachrisson BU, Minster L, Ogaard B, Birkhed D. Dental health assessed after interproximal enamel reduction: caries risk in posterior teeth. *Am J Orthod Dentofacial Orthop*. 2011;139(1):90-98. [CrossRef]

16. Iplinsky NT, Gandini Junior LG, Gandini AS, et al. Radiographic evaluation of enamel thickness of permanent teeth: relevance and applicability. *Dental Press J Orthod*. 2024;29(3). [CrossRef]

17. Harris EF, Hicks JD. A radiographic assessment of enamel thickness in human maxillary incisors. *Arch Oral Biol*. 1998;43(10):825-831. [CrossRef]

18. Hall NE, Lindauer SJ, Tüfekçi E, Shroff B. Predictors of variation in mandibular incisor enamel thickness. *J Am Dent Assoc*. 2007;138(6):809-815. [CrossRef]

19. Danesh G, Hellak A, Lippold C, Ziebura T, Schafer E. Enamel surfaces following interproximal reduction with different methods. *Angle Orthod*. 2007;77(6):1004-1010. [CrossRef]

20. Atsu SS, Aka PS, Kucukesmen HC, Kilicarslan MA, Atakan C. Age-related changes in tooth enamel as measured by electron microscopy: implications for porcelain laminate veneers. *J Prosthet Dent*. 2005;94(4):336-341. [CrossRef]

21. Peck S, Peck H. Crown dimensions and mandibular incisor alignment. *Angle Orthod*. 1972;42(2):148-153. [CrossRef]

22. Moss ML, Moss-Salentijn L. Analysis of developmental processes possibly related to human dental sexual dimorphism in permanent and deciduous canines. *Am J Phys Anthropol*. 1977;46(3):407-413. [CrossRef]

23. Konstantinidou E, Araujo E, Mccray J, Ueno H, Schneider PP, Foley PF. Evaluation of enamel thickness of mandibular incisors. *Dental Press J Orthod*. 2023;28(2). [CrossRef]

24. Schwartz GT. Enamel thickness and the helicoidal wear plane in modern human mandibular molars. *Arch Oral Biol*. 2000;45(5):401-409. [CrossRef]

25. Macha A de C, Vellini-Ferreira F, Scavone-Junior H, Ferreira RI. Mesiodistal width and proximal enamel thickness of maxillary first bicuspids. *Braz Oral Res*. 2010;24(1):58-63. [CrossRef]

26. Fernandes SA, Vellini-Ferreira F, Scavone-Junior H, Ferreira RI. Crown dimensions and proximal enamel thickness of mandibular second bicuspids. *Braz Oral Res*. 2011;25(4):324-330. [CrossRef]

27. Abdi CM. The newest African-Americans?: Somali struggles for belonging. In: Armila P, Kananen M, Kontkanen Y. (eds) The contexts of diaspora citizenship. International perspectives on migration, vol 17. Springer, Cham. [CrossRef]

28. The Editors of Encyclopaedia Britannica (2021, February 11). *Caucasian peoples.* Encyclopedia Britannica. [CrossRef]

29. Çelik A, Ersan N, Selvi-Kuvvetli S. Evaluation of maxillary sinus pathologies in children and adolescents with cleft lip and palate using cone beam computed tomography: a retrospective study. *Cleft Palate Craniofac J*. 2025 Feb 9:10556656241306834. Online ahead of print [CrossRef]

30. Dindaroğlu F, Fırıncıoğulları EC, Duran GS. Three-dimensional evaluation of social smile asymmetry in patients with unilateral impacted maxillary canine: a 3D stereophotogrammetry study. *Clin Oral Investig*. 2023;27(11):6915-6924. [CrossRef]