EVALUATION OF COINCIDENCE OF GINGIVAL ZENITH AND VERTICALLY BISECTED MIDLINE IN ANTERIOR TEETH: A CROSS-SECTIONAL STUDY

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ABSTRACT

OBJECTIVES

This study aimed to evaluate the coincidence and displacement of the gingival zenith in relation to the VBM of maxillary anterior teeth and to examine possible gender differences.

METHODOLOGY

A cross-sectional study was conducted with a non-probability consecutive sampling technique on 100 patients aged 18-30 at the outpatient department of Rehman College of Dentistry. Maxillary impressions were taken and poured in type IV dental stone. A digital caliper measured the gingival zenith and VBM on the casts, along with a pico-coronal displacement of lateral incisors. Data were analyzed using SPSS v22 with appropriate statistical tests (Shapiro-Wilk, t-test/Mann-Whitney U, chi-square), with significance set at $p < 0.05$.

RESULTS

With mean shifts of 0.70-0.84 mm and no significant gender differences (parametric effect size $d = 0.25$-0.35; 95% CI; $p>0.05$), gingival zenith displacement was more prevalent in central incisors (>90%). Minor nonparametric effects were observed in canines and lateral incisors ($r < 0.081$), with canines most aligned with VBM.

CONCLUSION

Displacement of the gingival zenith is common in maxillary anterior teeth, particularly in central incisors, while canines show the greatest likelihood of coincidence with the VBM. Gender did not influence gingival zenith position. Careful assessment of zenith position is recommended when planning esthetic dental treatments.

KEYWORDS: *Gingival Zenith, Vertically Bisected Midline, Apico-Coronal Displacement.*

INTRODUCTION

Beauty is often regarded as a harmonious integration of features that evoke a sense of balance, admiration, and aesthetic pleasure. Among the most significant contributors to first impressions are facial appearance and the quality of one's smile, both of which can have a lasting impact.[1] With the increasing emphasis on facial and dental aesthetics in contemporary society, there has been a substantial rise in the demand for restorative and cosmetic dental procedures. An aesthetically pleasing smile not only improves physical appearance but also enhances self-esteem and social confidence, reinforcing the role of dental esthetics in overall well-being.[2] Restorations that enhance dental appearance have been shown to influence a patient's self-image positively.[3] The gingiva's morphology, contour, and health are critical in determining smile attractiveness, and irregular gingival form can significantly affect esthetic outcome.[4] Therefore, integrating functional and esthetic elements requires careful consideration of the dento-gingival interface.[5] Existing literature emphasizes the significance of the gingival zenith in esthetics. The gingival line, defined by the connection of zenith points of the central incisors and canines, plays a pivotal role in gingival morphology. The zenith, being the most apical point of the gingival margin, directly affects tooth inclination and emergence profile.[6] previous studies have reported variability in the zenith positions of maxillary anterior teeth. For example, Magne and Belser identified the zenith of anterior teeth as displaced from their long axes.[7] While Rufenacht noted distal placement for central incisors and canines, but alignment with the tooth axis for lateral incisors. Studies have further shown that in most cases, the gingival zenith of central incisors lies distal to the vertical bisector, with minor gender-related differences.[8,9] Other investigations by Chu et al.,

Mattos, and Santana reported distal displacement of the gingival zeniths in canines, with relatively less displacement in lateral incisors.[10] Similarly, Zagar et al. demonstrated distal displacement in varying proportions across central, lateral, and canine teeth.[11] Given the importance of gingival zenith positioning in achieving esthetic outcomes, further clinical guidelines tailored to different populations are needed, particularly for use in esthetic restorative procedures where gingival contours are modified. A study of a Pakistani population found that distal displacement is more prevalent in central and lateral incisors.[19] Axial inclination, emergence profile, and general harmony of the smile are all influenced by the gingival zenith, which is a crucial factor in anterior dental aesthetics. Significant population-specific differences have been documented among ethnic groups, even though the distal displacement of the gingival zenith in maxillary anterior teeth is frequently highlighted in international literature. Gingival zenith behavior in the Khyber Pakhtunkhwa (KP) region was not explicitly studied until recently, and there remains a dearth of data in Pakistan. Distal gingival zenith deviations were primarily found in the central and lateral incisors, with age-related increases in deviation, but no gender differences, according to the only national-level data from Pakistan currently available. Although applicable, this single study does not accurately reflect the KP population.

METHODOLOGY

This cross-sectional study was conducted at the outpatient department of Rehman College of Dentistry, RMI Peshawar, from 2022 to 2025, following approval from RMI and the College of Physicians and Surgeons Pakistan (CPSP). A sample size of 100 was calculated using the WHO sample size calculator, with a 95% confidence level and a 10% margin of error.[11] Participants were selected using a non-probability consecutive sampling technique. Patients included in the study were males and females aged 18 to 30 years with well-aligned maxillary anterior sextants exhibiting normal gingival contour and structure, who visited the prosthodontics department of RCD for fixed restorations to improve esthetics and smile. Only patients with no previous history of orthodontic or periodontal treatment were included. Exclusion criteria comprised individuals with evidence of tooth alterations such as traumatic injury, occlusal wear, or cervical abrasion, as assessed by history, clinical examination, and radiographs. Patients with gingival alterations, including hyperplasia, inflammation, attachment loss, gingival recession, or a history of periodontal surgery, were also excluded. Further exclusions were applied to those with missing anterior teeth, crowding, a history of orthodontic or prosthodontic treatment, and diastema, as determined clinically and radiographically. The patients were informed of the study's advantages and goals, and verbal informed consent was obtained. Participants were stratified by biological gender (male, female) to assess potential gender-related differences in gingival zenith position; the sample included 50 males and 50 females. Gender comparisons were treated as secondary analyses; the study was primarily powered to estimate the prevalence and magnitude of gingival zenith displacement in the overall sample. Data were analyzed in the statistical programme SPSS (version 22). A maxillary arch imprint was taken using cavex cream alginate (CAVEX HOLLAND), and type IV dental stone was poured into the impression to create a stone cast. Inter-observer variability did not apply because all measures were obtained by a single, qualified examiner using a calibrated digital caliper and a defined technique. Consistency was maintained through repeated landmark verification, using the same measurement methodologies throughout and according to established protocols used in prior gingival zenith morphometric research. The tooth width was measured at two reference positions with a digital caliper to determine the vertically bisected midline (VBM) of each clinical crown on the cast. The reference positions were the proximal incisal contact point and the apical contact point. The center point of each width's division into halves was noted. To determine the vertically bisected midline, the center points were stretched along a line toward the gingival side of the clinical crown. The most apical point on the free gingival margin is used to determine the gingival zenith for each tooth, as shown in Figure 1. The gingival zenith, or its displacement from midline, was noted. A tangent line (gingival aesthetic line) was drawn on the diagnostic castings from the gingival zenith positions of the central incisor and canine on the ipsilateral sides, and the distance of the lateral incisor zenith in an apical-coronal direction was noted as shown in Figure 2.[18]

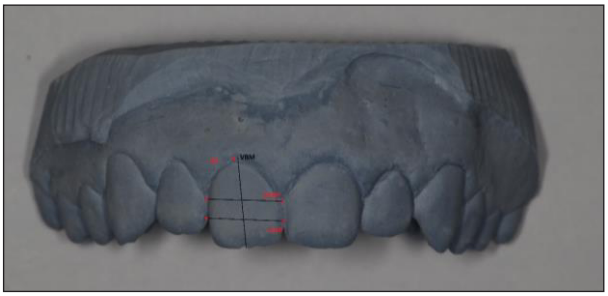

Figure 1: Determination of Vertically Bisected Midline (VBM) and Gingival Zenith Point (GZ), Apical Contact Area Point (ACAP), Incisal Contact Area Point (ICAP)

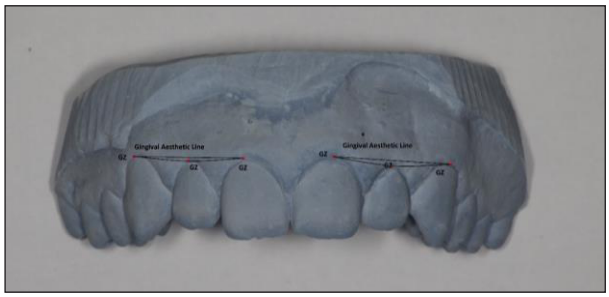

Figure 2: Determination of The Gingival Aesthetic Line

RESULTS

Normality of the data was assessed using the Shapiro-Wilk test, which indicated that measurements of the right and left central incisors were normally distributed ($p > 0.05$). In contrast, measurements of the lateral incisors and canines for both genders showed significant deviation from normality ($p < 0.001$). Mean and standard deviation were reported for data normally distributed, and median [IQR] was reported for non-distributed data. Comparison of outcomes was analyzed by applying the Independent t-test/ Mann–Whitney U test. The chi-square test analyzed the frequency of coincidence. The analysis of gingival zenith positions at a 95% confidence interval in the anterior sextant revealed no statistically significant gender differences across all teeth ($p > 0.05$). Overall, gingival zenith positions showed a tooth-dependent trend**:** central incisors were the most displaced, with right and left central incisors' effect size (Cohen's d ranging from 0.25 to 0.35) showing minimal to moderate gender-based differences, and canines showed the highest tendency for coinciding zeniths. While lateral incisors and canines showed nonparametric size effects of 0.081 and 0.02, respectively, supporting the conclusion that gender differences are negligible. Apico-coronal displacement of the lateral incisors was minimal and comparable between genders.

Table 1: Shapiro-Wilk Normality Test for Gingival Zenith Measurements

Tooth	Gender	P-Value
Right Central Incisor	Male	0.138
	Female	0.090
Left Central Incisor	Male	0.072
	Female	0.007
Right Lateral Incisor	Male	0.000
	Female	0.000
Left Lateral Incisor	Male	0.000
	Female	0.000
Right Canine	Male	0.000
	Female	0.000
Left Canine	Male	0.000
	Female	0.000

Table 2: Descriptive Statistics for Gingival Zenith in Anterior Sextant

Tooth	Gender	Mean±SD/Median (IQR)(mm)	P-value
Right Central Incisor (UR1)	Male	0.71 ± .40 mm	0.22
	Female	0.81±.40 mm	
Left Central Incisor (UL1)	Male	0.70± .41 mm	0.08
	Female	0.84± .41 mm	
Right Lateral Incisor (UR2)	Male	0.20 (.60) mm	0.41
	Female	0.30 (.52) mm	
Left Lateral Incisor (UL2)	Male	0.700 (.50) mm	0.84
	Female	0.80 (.40) mm	
Right Canine (UR3)	Male	0.10 (.42) mm	1.0
	Female	0.05 (.32) mm	
Left Canine (UL3)	Male	0.10 (.22) mm	0.83
	Female	0.05 (.33) mm	

Table 3: Apico-Coronal Displacement of Lateral Incisors by Gender

Tooth	Gender	Median (IQR) (mm)	P- value
Right Lateral Incisor (UR2)	Male	1.10 (0.20) mm	0.83
	Female	1.10 (0.40) mm	
Left Lateral Incisor (UL2)	Male	1.20 (0.40) mm	0.52
	Female	1.20 (0.32) mm	

Table 4: Frequency of Coinciding vs Displaced Zenith Points by Gender

Tooth	Gender	Coinciding (n, %)	Displaced (n, %)	P-value
Right Central Incisor(UR1)	Male	3, 6 %	47, 94%	0.93
	Female	3, 6%	47, 94%	
Left Central Incisor(UL1)	Male	2, 4%	48, 96%	0.76
	Female	1, 2%	49, 98%	
Right Lateral Incisor(UR2)	Male	17, 34%	33, 66%	0.92
	Female	12, 24%	38, 76%	
Left Lateral Incisor(UL2)	Male	13, 26%	37, 74%	0.89
	Female	16, 32%	34, 68%	
Right Canine (UR3)	Male	22, 44%	28, 56%	0.97
	Female	25, 50%	25, 50%	
Left Canine (UL3)	Male	20,40%	30, 60 %	0.72
	Female	25, 50 %	25, 50 %	

DISCUSSION

This study examined the positional association between the gingival zenith and the vertically bisected midline (VBM) in maxillary anterior teeth. The findings demonstrated that the gingival zenith did not align with the VBM in most cases, though no statistically significant gender differences were identified ($p > 0.05$). These results reflect the natural variability of soft tissue and dental midline alignment, underscoring the importance of individualized evaluation during esthetic treatment planning, particularly in smile design and anterior restorations. In this study, the gingival zenith consistently showed distal positioning relative to the anterior teeth, consistent with the results of Felipe V. [12] Central incisors exhibited the lowest rates of

coincidence (2-6%), whereas lateral incisors demonstrated moderately higher coincidence (24-32%). Canines displayed the highest coincidence rates (40-50%), indicating a more balanced distribution of zenith placement. These results are consistent with previous studies, such as those by Mattos and Santana, who reported distal zenith displacement across canines, laterals, and centrals in varying proportions.[13] Despite differences among tooth types, tooth shapes, and gingival biotypes, no statistically significant gender differences were found, aligning with reports from Appukuttan et al. and Chu et al., showing displacements between 0.7 and 1.2 mm.[14,15] Apico-coronal displacement of lateral incisors showed no gender-specific differences, with consistent median values, comparable to findings by Gaddale.[16,17] The clinical relevance of understanding zenith positioning lies in its impact on tooth proportion, gingival contour, and overall smile harmony. Ideally, central incisors and canines exhibit zeniths slightly distal to the VBM, while lateral incisors typically align with it, creating natural gingival curvature and symmetry. Deviations from these norms may compromise esthetic outcomes in smile design and restorative procedures. These results are consistent with earlier research showing that gingival architecture is subject to significant inter-individual variability even within the same demographic group, suggesting that individual anatomical factors may strongly influence biological variability in gingival form than by gender. The gingival biotype, which varies in thickness, shape, and recession susceptibility, may be a significant biological cause for this heterogeneity. While thinner biotypes are associated with increased scalloping and apical migration of the zenith, thicker, fibrotic biotypes often exhibit more stable, less scalloped gingival edges. The small magnitude of displacement differences between genders indicates that biotype distribution may be relatively similar between male and female patients in this population, even though biotype was not directly measured in this study. Clinically, these results imply that gender-based assumptions are not justified when planning esthetic restorations or gingival recontouring in the anterior maxilla. Additionally, localized anatomic features, such as tooth prominence, root angulation, and alveolar crest morphology, may be more important than demographic variables in determining zenith location. Ignoring patient-specific gingival zenith variability can result in non-ideal emerging profiles, asymmetric gingival contours, or poor pink-white esthetics in restorative and implant treatments, particularly in the esthetic zone. This bolsters arguments for including gingival zenith assessment into processes for digital smile design and pre-operative planning.

LIMITATIONS

One of the main strengths of this study is that it addresses an important aspect of dental esthetics by systematically evaluating the relationship between the gingival zenith and the vertically bisected midline in maxillary anterior teeth. The use of well-defined inclusion criteria and standardized measurement methods provided clarity and consistency in data collection. In addition, the study provides valuable baseline information for clinicians, particularly for treatment planning in restorative and esthetic dentistry. However, several limitations should also be considered. This was a single-center, cross-sectional study conducted with a relatively small sample of young adults aged 18-30 years, limiting the generalizability of the results to broader populations. The use of consecutive, non-random sampling may have introduced selection bias. Measurements were made on stone casts obtained from alginate impressions, which are prone to minor dimensional changes, and examiner calibration or reliability testing was not reported, leaving room for operator-related variability. Important clinical variables, such as gingival biotype, smile line, arch form, and tooth shape, were not evaluated, which could have influenced the results. Finally, being cross-sectional, the study does not provide insight into how the gingival zenith position may change over time or following dental treatment. Future studies with larger, more diverse samples, digital intraoral scanning to improve accuracy, and longitudinal follow-up are recommended to build on these findings and establish more generalizable clinical guidelines.

CONCLUSIONS

With central incisors exhibiting the most significant displacement and canines exhibiting the positional stability, the gingival zenith seldom aligns with the vertically bisected midline. Since gender had no discernible impact, these results highlight the need for individualized evaluation rather than relying on broad aesthetic standards. To achieve harmonious gingival architecture, canines can serve as reliable reference points in clinical settings. To improve aesthetic standards, more research using bigger, digitally evaluated samples is advised.

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Sajid Ali *- Concept & Design; Data Acquisition; Data Analysis/Interpretation; Drafting Manuscript; Critical Revision; Supervision; Final Approval*

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Izazullah *- Concept & Design; Data Acquisition; Drafting Manuscript; Final Approval*

The authors accept responsibility for all aspects of the work and will ensure that any concerns regarding the accuracy or integrity of any part are properly investigated and resolved.