ORIGINAL ARTICLE

Gingival Zenith Variations in Maxillary Anterior Teeth Across Age and Gender in The Pakistani Population

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ABSTRACT

Background: The gingival zenith plays a crucial role in influencing axial alignment and prosthetic contours. Therefore, its spatial disposition serves as a key reference for aesthetic restorations. The study examined gingival zenith position (GZP) variations in anterior maxillary teeth across different age groups and genders in the Pakistani population.

Methods: This cross-sectional study was carried out in the clinical setting of Islamic International Dental Hospital (IIDH) from July 2022 through August 2024 on the patients who came into the out-patient department of IIDH, which included 133 participants aged 21–60 years selected by a consecutive sampling technique. GZP was measured about the vertical bisecting midline using a digital caliper on dental casts. Data analysis was conducted using IBM SPSS version 25, with chi-square tests for categorical variables, independent t-tests for gender differences, and ANOVA for age group comparisons, with a significance level set at 0.05.

Results: The sample comprised 44(33%) young adults (16–25 years) and 62% females. Distal gingival zenith deviations were most common in central and lateral incisors, with the highest rate in the left lateral incisor (56%). Canines showed nearly equal rates of no deviation and distal deviation (49% each). Mean deviations were highest in central incisors (0.33 ± 0.49). While gender had no significant impact ($p > 0.05$), age significantly influenced deviations in central incisors, the right lateral incisor, and canines ($p < 0.05$), with older participants exhibiting more distal deviations.

Conclusion: Distal deviation is predominant in central and lateral incisors, correlating with age but not gender. These findings underscore the importance of age-specific reference points in periodontal and restorative procedures.

Keywords: Gingiva, Architecture, Prosthesis, Aesthetics.

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INTRODUCTION

One of the important contributors to dental aesthetics is good gingival harmony with the respective teeth[1]. Therefore, Prosthetic contours must align with healthy gums for a natural look. To achieve this, studying natural tooth-gingiva patterns is key[2]. Historically, the Golden proportion has guided dental aesthetics, yet deeper study is needed, especially for anterior aesthetics[3,4,5].Dental aesthetics include the "white" (tooth form, color, symmetry) and "pink" (gingival architecture) components[2]. Their harmony is crucial, especially in anterior zones[6].

The gingival zenith, marking the apical limit of the free gingival margin, varies across the maxillary anterior[7]. Its exact position remains debated, but its precise placement affects axial alignment, prosthesis profile, and soft tissue symmetry [5,8].

Meeting aesthetic demands requires understanding population-specific parameters[9]. Literature has shown that Gingival zenith can be adjusted via gingivo-plasty[10], crown lengthening[11], or bone grafting[12]

Variations in gingival zenith position (GZP) affect the esthetic outcome of anterior restorations. While previous studies have reported population-based differences in GZP, no such data exists for the Pakistani population. This study aimed to fill that gap by analyzing age and gender related GZP variations, enhancing prosthetic accuracy for natural and esthetic restorations.

METHODS

This cross-sectional study was conducted on patients visiting the Prosthodontics Department at Islamic International Dental Hospital, Islamabad, from July 2022 through August 2024. The sample size was calculated using Wang and Chow's (2007) formula[13] for comparing proportions, based on prior literature[14] with central incisor deviation rates of 29.68% (no deviation) and 15.62% (mesial deviation). A 95% confidence level ($Z_a/_2 = 1.96$) and 80% power ($Z\beta = 0.84$) determined the required sample size to be 133. The sampling technique was Non-consecutive sampling.

After receiving Ethical approval (Ref.No: IIDC/IRC/2022/006/006), the data collection was started. Participants aged 21–60 years with healthy, aligned, and unrestored anterior maxillary teeth were included. Exclusion criteria comprised missing, damaged, or misaligned anterior maxillary teeth, periodontal disease, and restorations. After obtaining ethical approval and informed consent, impressions of the maxillary arch were taken using irreversible hydrocolloid material (CavexCA37, Cavex) and cast in dental stone (Kopo Hard CKH-52, KuangPang Gypsum, Taiwan). The incisal and gingival contact points were identified, connected into mesio-distal reference lines **(Fig. 1)**, and bisected vertically **(Fig. 2)**. The Gingival zenith position (GZP) was identified **(Fig. 3)**. Its deviation from bisecting midline was measured using a digital Vernier caliper **(Fig. 4)**.
Data analysis was performed using SPSS version 22. The study analyzed gingival zenith position (GZP) variations in maxillary anteriors across four age groups (16–25, 26–35, 36–45, >45) and genders. Key variables included GZP and deviations for central incisors, lateral incisors, and canines. Statistical tests (chi-square, t-test, ANOVA) assessed categorical, gender-based, and age-related differences. Findings enhance understanding of gingival architecture, aiding aesthetic dentistry and clinical decisions.

Figure 1: Mesio distal lines running across incisal and gingival contact points

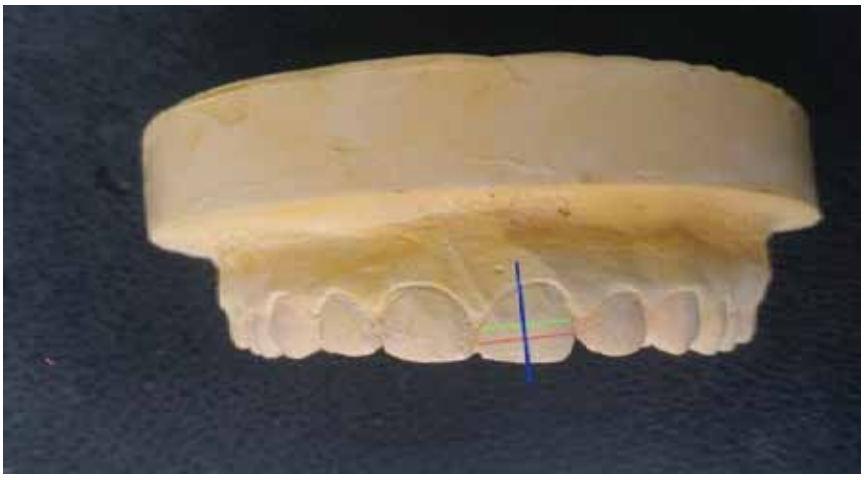

Figure 2: A vertical line bisects the mesiodistal lines in the exact center.

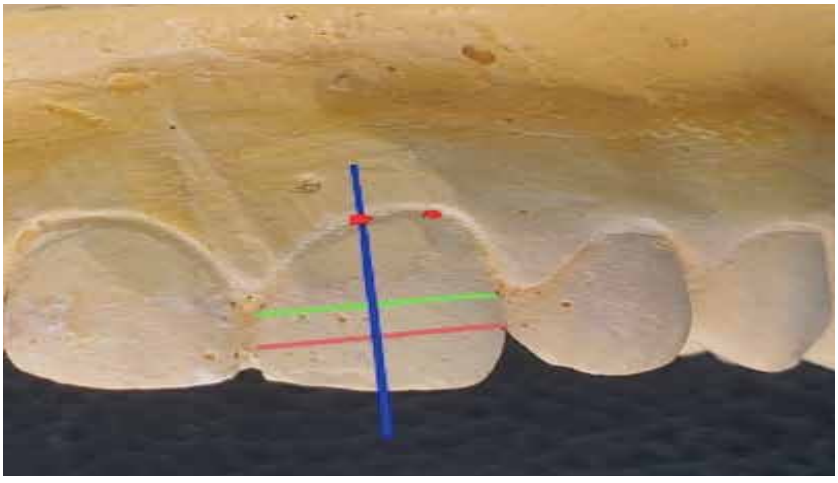

Figure 3: The Highest point of the gingival margin is identified and is the Gingival Zenith Position

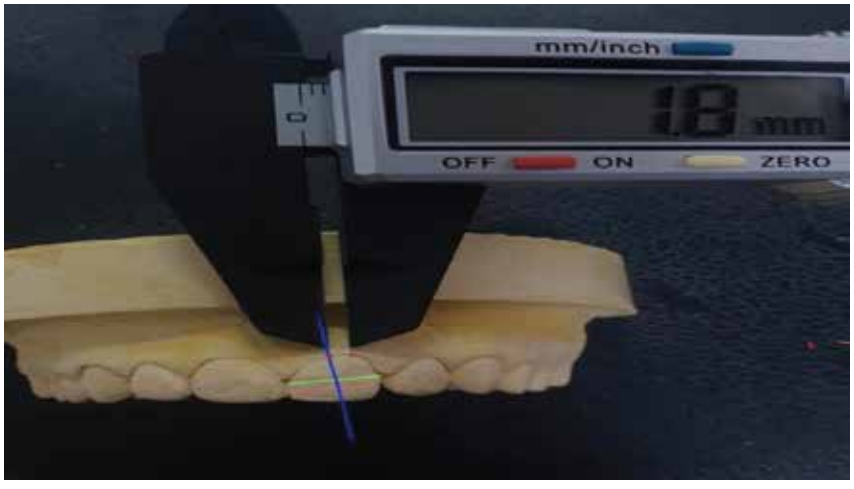

Figure 4: Digital caliper used to calculate distance between Vertical Bisecting midline and Gingival zenith position

RESULTS

Table 1. Frequency and Percentage of Qualitative Variables and Quantitative Variables

Variables	n(%) / Mean ± SD
Age (years)	
16-25	44(33%)
26-35	35(26%)
36-45	30(21%)
>45	24(18%)
Gender	
Male	50(38%)
Female	83(62%)
Left CI deviation	
No Deviation	67(50%)
Mesial	4(3%)
Distal	62(47%)
Right CI Deviation	
No Deviation	74(56%)
Mesial	5(4%)
Distal	54(41%)
Left LI Deviation	
No Deviation	56(42%)
Mesial	3(2%)
Distal	74(56%)
Right LI Deviation	
No Deviation	79(59%)

Mesial	3(2%)
Distal	51(38%)
Left Canine Deviation	
No Deviation	65(49%)
Mesial	3(2%)
Distal	65(49%)
Right Canine Deviation	
No Deviation	64(48%)
Mesial	6(5%)
Distal	63(47%)
Left CI	0.33±0.49
Right CI	0.31±0.52
Left LI	0.25±0.37
Right LI	0.22±0.41
Left Canine	0.24±0.34
Right Canine	0.25±0.4

The study analyzed age, gender distribution, and gingival zenith deviations in anterior maxillary teeth. Participants were mostly aged 16–25 (33%), followed by 26–35 (26%), 36–45 (23%), and >45 (18%). Females made up 62% of the sample. As shown in **Table 1**, Distal deviations were predominant in central incisors (Left CI: 47%, Right CI: 41%), while mesial deviations were minimal (Left CI: 3%, Right CI: 4%). Lateral incisors also showed a higher rate of distal deviations (Left LI: 56%, Right LI: 38%) than mesial deviations (Left LI: 2%, Right LI: 2%), with no deviation in 42% and 59% of cases, respectively. Canines had nearly equal rates of no deviation and distal deviation (49% each), with mesial deviations being the least frequent (Left Canine: 2%, Right Canine: 5%).

Quantitative analysis showed mean deviations ranging from 0.22 ± 0.41 to 0.33 ± 0.49, with central incisors having the highest mean deviations. These findings underscore significant variations in gingival zenith positions, stressing the need for customized dental aesthetic considerations based on age, gender, and tooth type.

Table 2. Association between Gingival Zenith Position of Maxillary Anterior Teeth and Gender

Variables	Male	Female	χ^2	p-value
Left CI deviation				
No Deviation	25(37%)	42(63%)	0.271	0.873
Mesial	2(50%)	2(50%)		
Distal	23(37%)	39(63%)		
Right CI Deviation				
No Deviation	26(35%)	48(65%)	1.43	0.490
Mesial	1(20%)	4(80%)		
Distal	23(43%)	31(57%)		
Left LI Deviation				
No Deviation	25(38%)	40(62%)	0.057	0.972
Mesial	1(33%)	2(67%)		
Distal	24(37%)	41(63%)		
Right LI Deviation				
No Deviation	24(38%)	40(63%)	0.053	0.974
Mesial	2(33%)	4(67%)		
Distal	24(38%)	39(62%)		
Left Canine Deviation				
No Deviation	19(34%)	37(66%)	1.48	0.477
Mesial	2(67%)	1(33%)		
Distal	29(39%)	45(61%)		
Right Canine Deviation				
No Deviation	31(39%)	48(61%)	0.229	0.892
Mesial	1(33%)	2(67%)		
Distal	18(35%)	33(65%)		

Table 2 analyzes the relationship between gender and gingival zenith position (GZP) deviations in maxillary anterior teeth. Chi-square test results indicate no significant gender-based differences ($p > 0.05$).

For both males and females, distal deviations were the most common across all teeth, with no significant differences in distribution. The left and right central incisors (Left CI: $p = 0.873$, Right CI: $p = 0.490$) and lateral incisors (Left LI: $p = 0.972$, Right LI: $p = 0.974$) showed similar deviation patterns in both genders. Canines followed the same trend (Left Canine: $p = 0.477$, Right Canine: $p = 0.892$). These findings suggest that gender does not influence GZP deviations, reinforcing its consistency in both males and females.

Table 3. Association between Gingival Zenith Position of Maxillary Anterior Teeth and Age

Variables	Age (years)					
	16-25 n=44	26-35 n=35	36-45 n=30	>45 n=24	χ^2	p-value
Left CI deviation						
No Deviation	31(46%)	19(28%)	7(10%)	10(15%)	21.42	0.002
Mesial	0(0%)	1(25%)	3(75%)	0(0%)		
Distal	13(21%)	15(24%)	20(32%)	14(23%)		
Right CI Deviation						
No Deviation	31(42%)	23(31%)	15(20%)	5(7%)	19.16	0.004
Mesial	2(40%)	0(0%)	1(20%)	2(40%)		
Distal	11(20%)	12(22%)	14(26%)	17(31%)		
Left LI Deviation						
No Deviation	27(42%)	18(28%)	12(18%)	8(12%)	9.77	0.135
Mesial	2(67%)	1(33%)	0(0%)	0(0%)		
Distal	15(23%)	16(25%)	18(28%)	16(25%)		
Right LI Deviation						
No Deviation	29(45%)	11(17%)	12(19%)	12(19%)	12.58	0.050
Mesial	2(33%)	1(17%)	1(17%)	2(33%)		
Distal	13(21%)	23(37%)	17(27%)	10(16%)		
Left Canine Deviation						
No Deviation	24(43%)	19(34%)	7(13%)	6(11%)	12.89	0.045
Mesial	1(33%)	0(0%)	1(33%)	1(33%)		
Distal	19(26%)	16(22%)	22(30%)	17(23%)		

Right Canine Deviation						
No Deviation	30(38%)	25(32%)	15(19%)	9(11%)	13.14	0.041
Mesial	0(0%)	0(0%)	1(33%)	2(67%)		
Distal	14(27%)	10(20%)	14(27%)	13(25%)		

Table 3 explores the association between gingival zenith position (GZP) deviations and age. Significant correlations were found for the central incisors ($p = 0.002$, $p = 0.004$), right lateral incisor ($p = 0.050$), and canines ($p < 0.05$), while the left lateral incisor showed no significance ($p = 0.135$).

No deviations were most common in younger individuals (Left CI: 46%, Right CI: 42%), while distal deviations increased with age, particularly in those 36 and older. Canines followed a similar pattern, with distal deviations peaking in the 36–45 group. These results suggest that GZP deviations increase with age, particularly in a distal direction, reinforcing the need for age-specific dental aesthetics.

Table 4: Comparison of Male and Female in Mean Scores of Gingival Zenith Position of Maxillary Anterior Teeth

Position	Male	Female	Independent samples t-test	
	Mean ± SD	*Mean ± SD*	t-value	p-value
Left CI	0.38±0.54	0.3±0.46	0.84	0.40
Right CI	0.37±0.54	0.27±0.5	1.08	0.28
Left LI	0.29±0.46	0.23±0.31	0.85	0.40
Right LI	0.2±0.36	0.23±0.44	-0.43	0.67
Left Canine	0.23±0.33	0.24±0.35	-0.21	0.83
Right Canine	0.24±0.36	0.27±0.43	-0.40	0.69

Table 4 compares gingival zenith position (GZP) deviations between males and females using an independent samples t-test, revealing no significant differences ($p > 0.05$). Males had slightly higher mean deviations in the central incisors, but the differences were not statistically significant. The lateral incisors and canines also showed no significant gender-based variation. These findings suggest that gender does not influence GZP deviations, reinforcing the consistency of GZP patterns across all teeth.

Table 5. Comparison of Patients of Different Age Groups in Mean Scores of Gingival Zenith Position of Maxillary Anterior Teeth

Position	Age(years)					
	16-25	26-35	36-45	>45	ANOVA	
	Mean ± SD	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	F-value	p-value
Left CI	0.19 ± 0.39^{a}	0.34 ± 0.49^{ab}	0.45 ± 0.55^{b}	0.42 ± 0.54^{ab}	2.783	0.044
Right CI	0.16±0.3	0.29±0.51	0.43±0.68	0.48±0.55	2.270	0.084

Left LI	0.24±0.36	0.25±0.47	0.24±0.28	0.28±0.38	2.173	0.094
Right LI	0.17±0.31	0.15±0.32	0.25±0.41	0.34±0.64	1.352	0.260
Left Canine	0.15±0.28	0.3±0.47	0.26±0.29	0.26±0.27	1.229	0.302
Right Canine	0.18±0.38	0.35±0.49	0.33±0.41	0.15±0.22	0.084	0.969

Note. Means with different letters are statistically significant at a=0.05

Table 5 compares gingival zenith position (GZP) deviations across age groups using ANOVA. A significant difference was found for the left central incisor ($p = 0.044$), with deviation increasing from 0.19 ± 0.39 (16–25 years) to 0.42 ± 0.54 (>45 years). The right central incisor showed a similar trend but was not statistically significant ($p = 0.084$). No significant variations were observed in the lateral incisors or canines ($p > 0.05$). These findings indicate that aging impacts the left central incisor's GZP, while other teeth remain stable.

DISCUSSION

The correct spatial positioning of the Gingival zenith position is necessary to achieve an ideal emergence contour and axial inclination[8]. This study defines GZP norms for age- and gender-based treatment, highlighting racial variations over universal patterns. Investigations into gingival zenith positioning (GZP) have been undertaken across various regions, including India[2,14], China[15], Saudi Arabia, Bangladesh[8], Ecuador[16], Uttarakhand[17] and Nepal[18]. However, this is the first comparative analysis by age and gender in Pakistan. It enriches clinical parameters, offering precise guidelines for age- and gender-specific gingival esthetic planning.

Central and lateral incisors mostly showed distal deviations, with almost half having no deviation. Canines had similar rates of no deviation and distal deviations. Mesial deviation was a rarity among all [6] teeth. These results are contrary to the majority of the literature stating most frequent distal deviation among C.I(96%), frequent in L.I(84%), and rare in canines(43%) [5,19], however, is common in the scarcity of mesial deviation of GZP[19,20].

Sex-based analyses reveal that gingival zenith (GZ) displacement may exhibit either congruence or divergence, contingent upon the studied population. A study found no gender differences in an Indian cohort, aligning with this study[14]. Conversely, another study observed greater distal displacement in male lateral incisors, while another reported higher GZP displacement in Ecuadorian females' central incisors[21]. A research noted frequent displacement in male central incisors but found no overall sex correlation[22] .

Aging induces passive eruption and mesial migration, altering gingival architecture. This study confirms increased distal GZP deviations in left central incisors with age, aligning with literature[14]. However, consistent with previous study no age-related correlation was observed for other teeth, which represented no association of GZP with the age of the subject[22] .

Gingival studies have used stone models, digital images[5], STL(Standard Tessellation Language) file [15]. While digital imaging is convenient, arch inclination and tooth tilt cause spatial distortions[14]. STL files offer 3D views but show minimal accuracy gains over stone models[23,24]. Following most studies[19], the present research employed stone casts and digital calipers for gingival zenith assessment[25].

CONCLUSION

Gingival zenith (GZ) attributed lack universality, with discrepancies arising from sample size, gender distribution, methodology, and ethnic composition. This study provides empirically grounded guidelines for precise GZ delineation, positioning, and axial alignment, which are essential for orthodontic and prosthetic interventions. Advanced technologies enable surgical precision, particularly in sub-millimeter gingivectomies. Clinically, these findings refine diagnostic and esthetic protocols for maxillary teeth, especially in the Pakistani population.

Further research within these demographics is warranted to explore additional gingival characteristics, such as the gingival line angle and interdental papillary heights and the intra-arch level of GZP of the lateral incisor relative to the Central incisor and canine.

CONFLICT OF INTEREST

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ETHICAL APPROVAL

The study received ethical approval from the Institutional Review Board of Islamic International Dental

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AUTHORS' CONTRIBUTIONS

AS contributed to the conceptualization and design of the study. **RA** was responsible for data collection, while **AG** reviewed the initial draft. **SS** played a key role in analyzing the results, and **PA** completed the final write-up of the manuscript.

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