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Original Article

Direct Versus Indirect Measurement of Height of The Interproximal Contact Area in Maxillary Anterior Teeth

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ABSTRACT

Objective: To compare interproximal contact area (ICA) height measurements obtained intraorally with those recorded on dental casts, in order to assess their accuracy and reliability.

Study Design: Cross-sectional comparative study.

Place and Duration of the Study: Department of Prosthodontics, Armed Forces Institute of Dentistry Rawalpindi, Pakistan from Dec 2024 to May 2025.

Methodology: A total of 90 participants with intact maxillary anterior teeth were included. ICA heights were measured intraorally using a digital caliper and compared with corresponding measurements taken on stone casts derived from alginate impressions. ICA was recorded between central incisors (CI–CI), central and lateral incisors (CI–LI), lateral incisors and canines (LI–C), and canines and first premolars (C–FP). Data was analyzed using paired t-tests, with $p<0.05$ considered statistically significant.

Results: Mean ICA heights were consistently greater on dental casts than intraorally. The highest values were noted between central incisors (4.79 ± 0.63 mm on casts vs. 4.42 ± 0.90 mm intraorally; $p = 0.003$). Similar significant discrepancies were found at CI–LI, LI–C, and C–FP sites (all $p<0.001$). Intraorally, the greatest ICA was at the CI–CI site, whereas the lowest was between the canine and first premolar on the right side.

Conclusion: Dental casts tend to overestimate ICA height compared to intraoral measurements. Intraoral assessments should be prioritized for accurate clinical evaluation.

Keywords: Anterior Teeth, Dental Casts, Interproximal Contact Area, Intraoral Measurement

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INTRODUCTION

The esthetic and functional integrity of the maxillary anterior dentition relies significantly on the morphology of the interproximal contact area (ICA).[1] As one of the primary determinants of smile harmony, the ICA is critical in avoiding food impaction, gingival health and interdental papilla support.[2] A precisely defined ICA leads to periodontal tissue stability and even distribution of occlusal forces.[3] From the esthetic view, its size and position significantly determine the occurrence or non-occurrence of interdental black triangles, which present a frequent patient complaint in the anterior region.[4] In view of the high aesthetic requirements of this region, precise assessment of the height of ICA is vital in restorative dentistry, orthodontics, implantology and periodontics, where even minor errors can jeopardize outcomes.[5]

A number of studies have measured height of ICA. Sghaireen *et al*. found that the height of ICA reduces from central to canine areas, with central–central contacts ranging from 2.9–6.5 mm and canine–premolar contacts from 0.6–2.5 mm.[6] Kolte et al. calculated the area of proximal contacts. They determined that the mean height from central incisors was 3.90 ± 0.93 m. Values declined distally with increased papilla fill in younger patients.[7] Kantrong *et al*. also demonstrated that mesiodistal tooth proportions influence ICA morphology, with width ratios of 0.72 for lateral-to-central and 0.80 for canine-to-lateral.[8] Sarig *et al*. demonstrated that proximal enamel thickness rose from ~0.63 mm in incisors to 1.48 mm in molars, reflecting consistent anatomical trends.[9] From a restorative perspective, Behzadi et al. found that there was no statistically significant difference in the tightness of proximal contact between direct and indirect restorations, although indirect restorations tended to make tighter contacts.[10]

Despite these observations, no consensus exists that intraoral direct or radiographic/digital indirect techniques are superior in their ability to measure ICA

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height in maxillary anterior teeth with greater accuracy. Direct techniques support real-time evaluation with operator variability and restriction by intraoral considerations, whereas indirect techniques ensure better reproducibility at the cost of not being representative of clinical conditions. Such comparison studies are still lacking in the anterior esthetic zone. This research aims to compare direct and indirect measurement methods of the interproximal contact area height of maxillary anterior teeth to determine which method is more clinically relevant and accurate.

METHODOLOGY

This cross-sectional study was carried out at the Department of Prosthodontics, Armed Forces Institute of Dentistry (AFID) Rawalpindi, Pakistan, from December 2024 to May 2025. Ethical clearance for the study was given by the Institutional Review Board (vide letter no 918/Trg/09/Feb/2003) and informed consent was obtained from all study participants before enrollment. Sample size was calculated using the WHO sample size calculator for paired means (two-sided α=0.05, power=80%) with the mean difference value observed (Δ=0.26 mm for right lateral incisor–canine contact) and assuming a within-subject correlation r=0.50 or ICA height measurements,[6] the sample needed was n=78 patients. Adding for ~10% possible loss of data (e.g., unusable records), the final target sample was fixed at 87–90 patients. Each patient provided measurements of the target contact using both direct (intraoral) and indirect (model) approaches. (Figure)

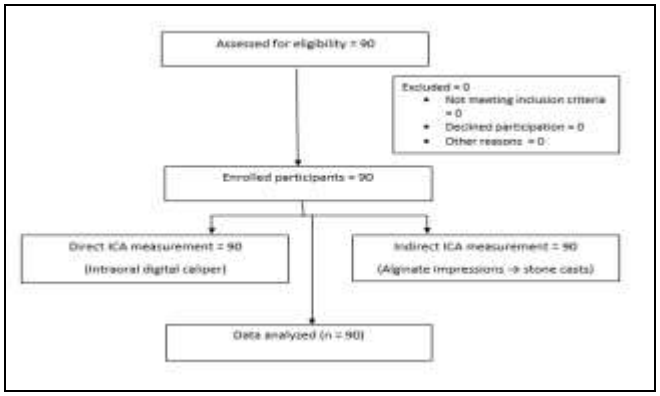

Figure: Patient flow diagram

Inclusion Criteria: Individuals aged 18 to 45 years who had fully erupted permanent maxillary anterior and premolars up to the first premolar. Participants with stable occlusion, healthy oral hygiene, and no visible caries or restorations on the proximal surfaces of the selected teeth were included.

Exclusion Criteria: Patients were excluded in the presence of missing or deformed anterior or premolar teeth, extensive caries, restorations or prostheses within the anterior segment. Patients with previous orthodontic treatment in the last 12 months, clinical evidence of periodontal disease like mobility or gingival recession that involves contact areas or systemic conditions that may affect the periodontal or dental status were also excluded.

A non-probability consecutive sampling of 90 participants (45 male and 45 female) was done. Interproximal contact areas (ICAs) were directly measured in the oral cavity with a digital caliper (Terensa, USA) that had a precision of 0.01 mm.6 The participants were all told to brush and floss before the procedure. Each proximal site was gently air-dried before measurement. The tapered, wedge-shaped tips of the caliper enabled positioning at both apical (gingival) and incisal (occlusal) ends of the contact area. The following contacts were measured on both right and left sides: Central incisor to central incisor (CI+CI), Central incisor to lateral incisor (CI–LI), Lateral incisor to canine (LI–C)and Canine to first premolar (C–FP).

Each contact was recorded three times and average value was noted to reduce error. For indirect measurements, maxillary alginate impressions (Hydrogum, Zhermack, Italy) were taken and disinfected at the spot. Casts were made in type III dental stone (Elite Model Thixotropic, Zhermack, Italy) with a vacuum mixer (Easy Mix, Bego, Germany). Impression or cast defects were removed and remade. The casts were all made and finished by one experienced dental technician to provide uniformity. At the casts, the height of the ICA was taken according to the method proposed by Stappert *et al.*, from the apical contact point (at the level of interdental papilla peak) to the incisal contact point (beginning of the incisal embrasure).[3] The same intraoral proximal contacts were scored on the casts. In order to guarantee reproducibility, intra-examiner reliability was determined by taking repeated ICA measurements in three participants a week later by the same examiner, and reliability was measured in terms of kappa statistics. Inter-examiner reliability was also verified by having another examiner take the same measurements on the same subset of participants.

Data was analyzed using Statistical Package for social sciences (SPSS) version 23. Continuous variables like interdental contact area (ICA), height and tooth dimensions were represented using mean and standard deviation, whereas frequencies and percentages were determined for categorical variables like gender and tooth type. Normality of continuous data was assessed using the Shapiro–Wilk test. ICA height data for both intraoral and model measurements showed normal distribution (p>0.05), while tooth dimension data also followed a normal distribution. Categorical variables were not subjected to normality testing.

As intraoral and model ICA measurements were obtained from the same participants, they were treated as dependent variables. Therefore, a paired t-test was applied to compare ICA heights between intraoral and corresponding model measurements for each contact site. To analyze differences in ICA height across multiple interproximal contact sites, repeated measures ANOVA was conducted. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 90 participants were included with a mean age of 30.72 ± 6.65 years. Mean ICA between central incisors (CI+CI) was significantly higher on casts (4.79 ± 0.63 mm) than intraoral measurements (4.42 ± 0.90 mm, p=0.003). In a similar way, there were large differences for all the other contacts such as CI–LI (R), LI–C (R), C–FP (R), CI–LI (L), LI–C (L), and C–FP (L), in which cast measurements all provided higher mean values compared to intraoral measurements (all p<0.001). These results suggest a systematic overestimation of ICA heights on dental casts compared to intraoral measurement (Table I).

The intraoral mean ICA heights between maxillary anterior teeth provided the greatest value between CI+CI (4.42 ± 0.90 mm), then CI–LI (L) (2.72 ± 0.58 mm) and CI–LI (R) (2.53 ± 0.38 mm). The lowest intraoral contact height was observed between C–FP (R) (1.29 ± 0.40 mm). The general comparison showed statistically significant difference between contact points (p<0.001), indicating differential proximal morphology on anterior teeth (Table-II). On dental casts, maximum ICA height was once more measured between CI+CI (4.79 ± 0.63 mm), while minimum mean value was recorded between C–FP (R) (1.66 ± 0.38 mm). Other contacts such as CI–LI (R: 2.91 ± 0.41 mm, L: 3.24 ± 0.79 mm) and LI–C (R: 2.59 ± 0.42 mm, L: 2.63 ± 0.32 mm) also showed greater measurements than intraoral results. The statistical difference among model-based ICA values was very significant (p<0.001) (Table-III).

DISCUSSION

It was observed in this study that the heights of the interproximal contact area (ICA) were higher on dental casts compared to intraoral measurements. The largest difference was seen between central incisors (4.79 ± 0.63 mm vs. 4.42 ± 0.90 mm, p = 0.003), with equivalent overestimations at CI–LI, LI–C, and C–FP sites (all p<0.001). Intraorally, the maximum ICA was recorded between central incisors, and the minimum between canine and first premolar on the right side. The findings accentuate systematic overestimation in cast measurements, and thus the need for intraoral evaluation to ensure accuracy. Proximal contact and interdental papillae maintenance are crucial for both function and esthetics of natural and prosthetic dentition. Varthis *et al*. emphasized that loss of

Table-I: Comparison of Interproximal Contact Area (ICA) Height Measured Intraorally Vs Dental Models (n = 90)

Variable(s)	Measurement Method	Mean ± SD	Minimum	Maximum	*p*-value
CI + CI	Intraoral	4.42 ± 0.90	2.45	6.85	0.003
	Model	4.79 ± 0.63	3.26	6.22	
CI-LI (R)	Intraoral	2.53 ± 0.38	1.74	4.01	< 0.001
	Model	2.91 ± 0.41	1.98	4.32	
LI-C (R)	Intraoral	2.24 ± 0.41	1.47	4.28	< 0.001
	Model	2.59 ± 0.42	1.84	4.52	
C-FP (R)	Intraoral	1.29 ± 0.40	0.5	2.17	< 0.001
	Model	1.66 ± 0.38	0.85	2.77	
CI-LI (L)	Intraoral	2.72 ± 0.58	1.63	5.02	< 0.001
	Model	3.24 ± 0.79	1.77	6.36	
LI-C (L)	Intraoral	2.21 ± 0.26	1.4	3.23	< 0.001
	Model	2.63 ± 0.32	1.86	3.74	
LI-C (L)	Intraoral	1.59 ± 0.29	0.77	2.32	< 0.001
	Model	1.95 ± 0.29	1.02	2.73	

CI–CI = central incisor–central incisor;
CI–LI = central incisor–lateral incisor;
LI–C = lateral incisor–canine;
C–FP = canine–first premolar; R = right; L = left.

interproximal contact (ICL) is quite a common condition, presenting more on the mesial surfaces than distal ones, with frequencies varying from 18% to 66% in the maxilla and 37% to 54% in the mandible.[11] Notably, this complication may arise as early as three months post-prosthetic therapy, highlighting the necessity of long-term follow-up for patients after rehabilitation. To supplement this, Esmaeli et al. highlighted the sensitivity of indirect clinical examination methods for assessing papilla size, which showed high correlation with direct measurement for papilla depth (88%), angle (98%), and width (90%).[12] This implies that non-invasive tests have the potential to be applied usefully both in research and in daily practice to record soft tissue change. On contact morphology, Zahra et al. found mean proximal contact area (PCA) values of 4 mm between central incisors, 3 mm between central and lateral incisors, and 2 mm between lateral incisors and canines, with mesial contact areas being larger than distal throughout.[13] Their statistical evaluation confirmed notable side differences ($p < 0.0001$), further emphasizing the relevance of symmetry to esthetic zones and its clinical significance in restorative dentistry. Additionally, the effect of aging on papilla health was established by Khaireddine *et al.*, who found a positive correlation between age and papilla score but negative with papilla height.[14] These results suggest that although older patients have greater papilla scores as a result of compensatory tissue alteration, there is a simultaneous loss of papillary height with particular relevance to the visibility of "black triangles." They also demonstrated that papilla height was significantly related to contact point height, further supporting the essential role of restorative design in maintaining soft tissue esthetics. Interproximal contact morphology is a key factor in interdental papilla stability and the avoidance of interproximal contact loss (ICL). Kolte *et al*. proved that the maxillary anterior papilla's dimensions, crestal papilla, and proximal contact area (PCA) have characteristic proportions, with most of the mesial contact areas being larger than distal contacts.[15] These ratios are important in maintaining the integrity of the interdental papilla since deficient PCA or disproportionate contact dimensions can predispose patients to black triangles and aesthetic issues. Moamen *et al*. in a systematic review and meta-analysis emphasized that interproximal contact loss is a comparatively common complication between implant restorations and adjacent teeth with a prevalence of 34.1% to 66%, especially in the mesial surfaces.[16] These results highlight the need to determine optimal contact dimensions and ratios in restorative and prosthetic treatments.

Table-II: Interproximal Contact Area (ICA) Heights Recorded Intraorally Among Maxillary Anterior Teeth (n = 90)

Variable(s)	Mean ± SD	*p* - value
CI + CI	4.42 ± 0.90	< 0.001
CI-LI (R)	2.53 ± 0.38	
LI-C (R)	2.24 ± 0.41	
C-FP (R)	1.29 ± 0.40	
CI-LI (L)	2.72 ± 0.58	
LI-C (L)	2.21 ± 0.26	
LI-C (L)	1.59 ± 0.29	

Table-III: Interproximal Contact Area (ICA) Heights Recorded on Dental Models Among Maxillary Anterior Teeth (n = 90)

Variable(s)	Mean ± SD	*p*-value
CI + CI	4.79 ± 0.63	< 0.001
CI-LI (R)	2.91 ± 0.41	
LI-C (R)	2.59 ± 0.42	
C-FP (R)	1.66 ± 0.38	
CI-LI (L)	3.24 ± 0.79	
LI-C (L)	2.63 ± 0.32	
LI-C (L)	1.95 ± 0.29	

CI–CI = central incisor–central incisor;
CI–LI = central incisor–lateral incisor;
LI–C = lateral incisor–canine;
C–FP = canine–first premolar; R = right; L = left.

Tooth size and width proportions between populations also need to be considered, as they directly influence the extent and morphology of interproximal contact areas (ICA). Larger mesiodistal tooth dimensions typically result in broader proximal contact areas, while smaller tooth widths lead to narrower or more point-like contacts. Alqahtani *et al*. in their research on a Saudi subpopulation, cited the mean width of central incisor as 8.63 ± 0.61 mm, lateral incisor 6.75 ± 0.56 mm, and canine 7.88 ± 0.64 mm, whereas the relative width proportion between central and lateral incisors was 78.2%, and that between lateral incisor and canine was 85.9%.[17] These values reflect population variations that can affect esthetic guidelines in planning anterior restorations. In addition, accurate measurement methods have a notable effect on the reliability of interproximal dimension measurements. Sghaireen *et al*. compared intraoral and extraoral assessments for measurement of interproximal contact height and concluded that intraoral measurements significantly exceeded extraoral measurements (mean difference of 0.21 ± 0.19

mm),[18] indicating the clinical superiority of intraoral assessment for more precise patient-specific planning.

One potential explanation for this systematic overestimation is the dimensional changes in the impression and cast materials. Although alginate impression materials are widely used due to their ease of manipulation, they are known to undergo slight expansion or distortion if not poured immediately, which can affect dimensional accuracy. Even when impressions are poured promptly, minor linear changes during setting of both alginate and dental stone may lead to subtle dimensional discrepancies between the cast and the actual intraoral situation. These small deviations, when accumulated, can influence precise linear measurements such as ICA height. Therefore, the findings of this study underscore the importance of prioritizing direct intraoral measurements for critical dimensional assessments. When cast measurements are used, careful standardization of impression-taking, storage time, and pouring protocols is essential to minimize dimensional errors.

LIMITATIONS OF THE STUDY

Variations in tooth size, papilla height, and proportions of contact areas have been found to differ among populations, indicating that wider, multi-ethnic studies are called for on a more universal basis. Secondly, the cross-sectional design gives a snapshot view of papillary and contact area relationships that are independent of age-related changes, differences in periodontal status, and dynamic effects of restorative and prosthetic interventions over time. Furthermore, even though intraoral measurements were made, past evidence has identified differences between intraoral and extraoral assessments of interproximal contact and papilla height and may have an impact on reproducibility. Lastly, the study did not evaluate patient-centered outcomes, including esthetic satisfaction or clinical performance of restorations, that are paramount in the translation of morphometric results into practice.

CONCLUSION

This study demonstrated that dental models consistently overestimated interproximal contact area (ICA) heights compared to intraoral measurements, with statistically significant differences observed across all contact points. The greatest ICA height was found between the central incisors, while the lowest was noted at the canine–first premolar region. These findings highlight morphological variations in anterior interproximal contacts and emphasize the importance of relying on intraoral measurements for precise clinical assessment, as cast-based evaluations may lead to systematic overestimation.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

MS & SK: Data acquisition, data analysis, critical review, approval of the final version to be published.

AA & AI: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

SS & SK: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

REFERENCES

1. Zhang Y, Hong G, Zhang Y, Sasaki K, Wu H. Minimally invasive procedures for deficient interdental papillae: A review. J Esthet Restor Dent 2020; 32(5): 463-471.https://doi:10.1111/jerd.12608
2. Khlef HN, Hajeer MY. Is it possible to achieve favorable accelerated dental changes with no periodontal complications when retracting upper anterior teeth assisted by flapless corticotomy compared to traditional corticotomy? A two-arm randomized controlled trial. Sci World J 2022; 2022: 4261248. https://doi:10.1155/2022/4261248
3. Stappert CF, Tarnow DP, Tan JH, Chu SJ. Proximal contact areas of the maxillary anterior dentition. Int J Periodontics Restorative Dent 2010; 30(5): 471-477.
4. Blandy MC. Assessment of the accuracy of interproximal tooth reduction using three-dimensional digital models. Townsville: James Cook University; 2015.
5. Khatri MP, Kishore S, Hemmanur S. Aesthetic smile designing [Internet]. London: IntechOpen; 2023. https://doi:10.5772/intechopen.86424
6. Sghaireen MG, Al-Zarea BK, Al-Shorman HM, Al-Omiri MK. Clinical measurement of the height of the interproximal contact area in maxillary anterior teeth. Int J Health Sci 2013; 7(3): 325-330. https://doi:10.12816/0006061
7. Kolte AP, Kolte RA, Bawankar P. Proximal contact areas of maxillary anterior teeth and their influence on interdental papilla. Saudi Dent J 2018; 30(4): 324-329. https://doi:10.1016/j.sdentj.2018.05.007
8. Kantrong N, Traiveat K, Wongkhantee S. Natural upper anterior teeth display an increasing proportion in mesio-distal direction. J Clin Exp Dent 2019; 11(10): e890-e897. https://doi:10.4317/jced.56206
9. Sarig R, Vardimon AD, Sussan C, Benny L, Sarne O, Hershkovitz I, 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. https://doi:10.1016/j.ajodo.2014.11.026
10. Behzadi S, Mohammadibassir M, Hamze F, Rezvani MB. Evaluating the proximal contact tightness in direct or in-direct restoration of endodontically treated teeth: Randomized clinical trial. J Clin Exp Dent 2024; 16(8): e931-e939. https://doi:10.4317/jced.61558
11. Varthis S, Tarnow DP, Randi A. Interproximal open contacts between implant restorations and adjacent teeth: prevalence, causes, possible solutions. J Prosthodont 2018; 28(2): e806-e810. https://doi:10.1111/jopr.12980
12. Esmaeli F, Shirmohammadi A, Faramarzie M, Abolfazli N, Rasouli H, Fallahi S. Determination of vertical interproximal bone loss topography: correlation between indirect digital radiographic measurement and clinical measurement. Iran J Radiol 2012; 9(2): 83-87. https://doi:10.5812/iranjradiol.7732

13. Syed ZS, Khan UR, Butt SA, Fayyaz A, Ahmad MU, Memon AA. Clinical measurement of proximal contact areas of maxillary anterior dentition. J Popul Ther Clin Pharmacol 2024; 31(2): e4313. https://doi.org/10.53555/jptcp.v31i2.4313
14. Khaireddine H, Mohamed T, Arij R, Faten K, Faten BA. Factors impacting the height of the interproximal papilla: A cross-sectional study. Clin Exp Dent Res 2023; 9(3): 449-454. https://doi.org/10.1002/cre2.728
15. Kolte AP, Kolte RA, Purohit MJ, Bajaj VA. Proportions in papilla, crestal papilla, and proximal contact area in maxillary anterior teeth: A cross-sectional study. J Indian Soc Periodontol 2022; 26(5): 492-497. https://doi.org/10.4103/jisp.jisp_251_21
16. Sheba M, Floriani F, Nimmo A, Ercoli C, Hosney S. Interproximal contact loss between implant restorations and adjacent natural teeth: A systematic review and meta-analysis. J Prosthodont 2023; 33(4): 313-323. https://doi.org/10.1111/jopr.13780
17. Alqahtani AS, Habib SR, Ali M, Alshahrani AS, Alotaibi NM, Alahaidib FA. Maxillary anterior teeth dimension and relative width proportion in a Saudi subpopulation. J Taibah Univ Med Sci 2021; 16(2): 209-216. https://doi.org/10.1016/j.jtumed.2020.12.009
18. Sghaireen MG, Albhiran HM, Alzoubi IA, Lynch E, Al-Omiri MK. Intraoral versus extraoral measurement of the height of the interproximal contact area in maxillary anterior teeth. Med Princ Pract 2015; 24(2): 136-141. https://doi.org/10.1159/000369903