CLINICAL MEASUREMENT OF PROXIMAL CONTACT AREAS OF MAXILLARY ANTERIOR DENTITION

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ABSTRACT:
Objectives: The primary aim of this study was to establish a database detailing the apico-incisal dimensions of proximal contact areas (PCA) and their corresponding proximal contact area proportions (PCAP) for maxillary anterior teeth (MAT).

Methods: This morphometric cross-sectional study involved 200 healthy participants was conducted at Lahore Medical & Dental College. A Digital Vernier Caliper (6-inch, 150 mm) was utilized and the clinical measurements were directly taken within each participant's oral cavity. Clinical parameters, the heights of PCAs and clinical crowns from the right to the left maxillary premolar, were recorded. PCAP values were derived using the formula: PCAP = (Height of mesial PCA of the corresponding tooth / Crown Length) $\times$ 100.

Results: A total of 1400 interdental sites (7 per participant) were measured. The statistical analysis revealed no significant relationship between age, gender, and the heights of proximal contact areas (P > 0.05). According to the Paired sample t-test, PCA dimensions exhibited significant differences on both sides of each tooth (P value < 0.0001). Mesial contacts areas were larger than distal contacts for each anterior tooth.

Conclusion: The study's findings showed a bilateral decrease in mean PCA and PCAP values as one moves away from the midline. Mean PCA values for contacts between central incisors, central-lateral incisors, and lateral incisor-canine were measured at 4 mm, 3 mm, and 2 mm, respectively. The generated database serves as a valuable guide for clinicians, aiding them in achieving optimal outcomes in restorative dentistry.

Keywords: Anterior (MeSH), Area (MeSH), Contact (MeSH), Dentition (MeSH), Digital Vernier Caliper (Non-MeSH), Measurement (MeSH), Proximal (MeSH), Teeth (MeSH)

INTRODUCTION:

In the modern world, an increasing number of patients express increased esthetic expectations, driven by a consciousness about their appearance and a desire for social acceptance. A captivating smile, however, is not solely dependent on the appearance of teeth but relies on a balanced and harmonious interaction between teeth as well as on the mucosal tissue. Within the umbrella of dental micro esthetics, one crucial component is the Proximal Contact Areas (PCAs), defined as the region of a tooth in close contact with an adjacent tooth in the same arch (1).

Research in dental anatomy and morphology has extensively examined the location of contact areas within the maxillary anterior teeth (MAT), focusing on their apico-incisal direction. The importance of the PCAs lies in its role in defining key esthetic and functional aspects (2). It serves to establish the gingival embrasure, influencing the height of the interdental papilla. Moreover, the PCAs contribute to shaping the incisal embrasure, which widens coronally from the point of contact as well as it also protect the periodontium, redistributing masticatory forces and preventing food impaction (3). This widening is essential for efficient mastication and imparts individuality to the anterior dentition. Weak or slightly open proximal contacts may lead to various issues, including caries, halitosis, unattractive appearance, and periodontal issues. The maintenance of proper incisal embrasure dimensions is vital for efficient mastication and contributes to the individuality of the anterior dentition (1, 4).

PCAs of an appropriate size and location are the integral component for achieving a healthy, functional, and aesthetically acceptable dentition (5, 6). True point contacts, characterized by nearly perfect curvatures on contacting surfaces, are typically observed in young patients with newly erupted teeth, particularly at the canines and first premolars. However, in adults, PCAs are more common in the anterior dentition (6, 7). The size of these areas varies based on the shape of the contacting tooth surfaces and is influenced by factors such as wear (5).

Clinically, the characteristics of the PCAs directly shape the gingival embrasure, height of the interdental papilla, and incisal embrasure, contributing for achieving optimal 'pink aesthetics'. PCAs also exhibit variations in dimensions influenced by tooth size, type, shape, position, as well as wear and attrition. A deviation in the dimensions of PCAs can result in aesthetic challenges. A smaller PCA may create the appearance of small black triangles, while a longer PCAs might impinge on the mucosa, causing an unpleasant appearance and potentially leading to periodontal problems (6, 8-11). Hence, when maneuvering for anterior dental restorations, careful consideration of the PCAs height is important due to its role in achieving the desired esthetic outcome.

In individuals with a high smile line, where cervical margins become visible, the careful consideration of the PCAs height becomes essential. Influential guidelines, such as Tarnow et al. (12) 'mm rule', highlight the critical nature of maintaining specific distances to ensure complete fill of the gingival embrasures, emphasizing the importance of PCAs height during anterior restorations. The positioning of the PCA has been explored in various research studies, such as Suilkowski's et al. (13), where it was noted to lie between the incisal and gingival embrasures. Stappert et al. (7) conducted their study of the measurements on master casts, assessing the PCAs from the apical point corresponding to the height of the interdental papilla to the incisal point equivalent to the beginning of the incisal embrasure. Their findings indicated a decrease in the PCAs antero-posteriorly between maxillary central incisors to first premolars bilaterally, diminishing from 4 to 3 mm and 2 to 1.5 mm, respectively. Other researchers, such as Tarnow et al. (12) and Martegani et al. (14), opted for different measurement approaches. They measured the distance between the bone crest and the facial aspect of the apical contact area using soft tissue sounding. Martegani et al. (14) further validated their results through periapical radiographs. The most apical portion of the PCAs was pinpointed using an innovative method involving a copper line fixed within the interdental embrasure. This study was

aimed to generate a database of PCAs of MAT by determining apico-incisal dimensions of PCAs and their proximal contact area proportions (PCAP).
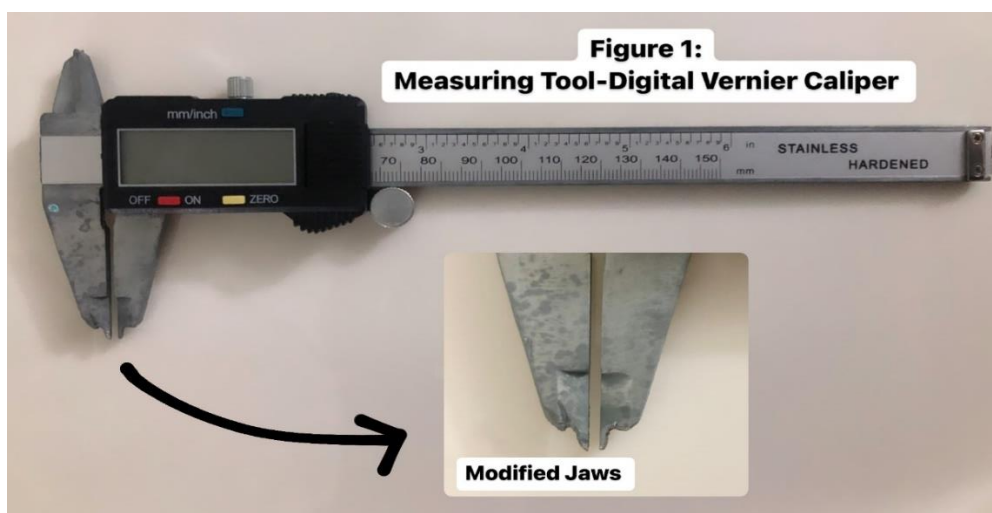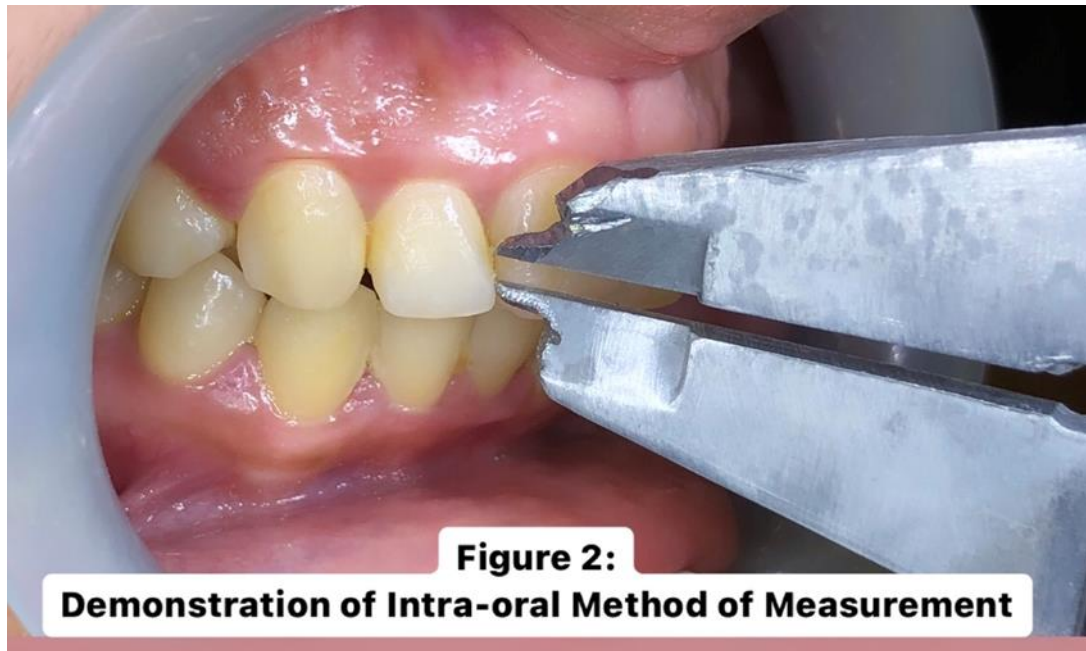
METHODOLOGY:

This morphometric cross-sectional study, conducted at the respected Dental Hospital of Lahore Medical & Dental College (LMDC) from October 2021 to October 2022. The sample size of 200 healthy participants was calculated by using the OpenEpi calculator, considering a 95% confidence interval and 80% power. A study by de Santana et al.(15), which reported mean ± S.D values for experimental and control groups (3.5 ± 0.7 and 3.2 ± 0.8, respectively), the total sample size of 198 was determined. To reduce the bias, each of the participants were randomly selected (on the basis of inclusion and exclusion criteria) included both dental professionals from LMDC's Dental Hospital and patients seeking services from the Operative Dentistry Department for their dental complain. The ethical consideration was taken into account and approval was taken from the ethical review board committee of LMDC (Ref # LMDC/FD/749/20). Every participant provided written consent, accompanied by the assurance of the right to withdraw without any consequences.

Our participants underwent through examinations to meet the inclusion criteria, which encompassed having fully erupted, well-aligned maxillary teeth and maintaining a healthy gingival status (Plaque & Gingival index score of 0–1). Those exhibiting suspected gingival inflammation underwent scaling and were included in the study after a two-week follow-up without inflammation. The exclusion criteria were patients with open proximal contacts, ongoing periodontal disease, and history of muco-gingival surgery, trauma, congenital defects, midline diastema, orthodontic treatment, presence of maxillary anterior crowns /prosthetic restorations, missing one or more MAT or the presence of carious lesion on MAT.

Our approach to data collection involved measuring the clinical parameters, specifically lengths of PCAs and clinical crowns from the right maxillary premolar to the left maxillary premolar. PCAPs were calculated using a precise formula: PCAP = (Length of mesial side PCA of the corresponding tooth / Crown Length) × 100. To ensure accurate measurements, a digital caliper with modified measuring ends was employed (6-inch, 150 mm) (Fig 1). Prior to measurement, participants were asked to rinse their oral cavity with water, and then MAT was air-dried with a triple syringe. Each PCA was measured thrice, and the average of these readings was recorded. Our study encompassed a total of seven interdental sites, spanning from the contact area between the right first premolar and right canine to the contact area between the left first premolar and left canine (Fig 2). Additionally, clinical crown heights for eight maxillary teeth were documented.

The collected data was analysed by using statistical software (SPSS 12 Chicago, IL, USA). Continuous variables, PCA & PCAP, were presented with as Mean ± SD, while categorical variables such as age and gender were expressed in numbers and percentages. The analytical approach employed a paired sample t-test, for comparison between mesial and distal PCAs for each individual tooth.

Figure 1:
Measuring Tool-Digital Vernier Caliper

Modified Jaws

Figure 2:
Demonstration of Intra-oral Method of Measurement

RESULTS:

A total no. of 200 participants (109 females, 91 males) fulfilled the criteria and participated in the study. A total number of 7 PCAs per participant and a total of 1400 PCAs were measured in this study. Mean age of the participants was 38 years old with 23 years old being the youngest participant and a 65 years old participant as the oldest. No correlation or dependence was found when age and gender were correlated with heights of proximal contact areas (P >0.05). Maximum PCA was found to be between both central incisors with mean value of 4 mm. The least PCA was found to be between distal contact of left canine and left first premolar with mean value was 1.4 mm. PCAP followed the similar trend and decreased from midline to laterally. Mean values of PCAs and PCAPs after rounding off are given in Table 1 and 2.

TABLE 1: PROXIMAL CONTACT AREA VALUES OF MAXILLARY ANTERIOR TEETH				
PCA sites	**Standard Deviation**	**Min.**	**Max.**	**Mean**
CI-CI (Tooth no. 11/21)	0.15154	3.60	4.0570	4.0570
Right CI-LI (Tooth no. 11/12)	0.13643	2.70	3.0235	3.0235
Right LI-CA (Tooth no. 12/13)	0.07248	1.60	1.8986	1.8986
Right CA-PM (Tooth no. 13/14)	0.01936	1.36	1.4152	1.4152
Left CI-LI (Tooth no. 21/22)	0.09476	2.53	2.8497	2.8497
Left LI-CA (Tooth no. 22/23)	0.28068	1.56	2.0278	2.0278
Left CA-PM (Tooth no. 23/24)	0.12683	1.22	1.4847	1.4847
CI: Central Incisor, LI:Lateral Incisor, CA: Canine, PM:1st Premolar *FDI World Dental Federation notation system is used for tooth numbering				

TABLE 2: DESCRIPTIVE STATISTICS - PROXIMAL CONTACT AREA PROPORTIONS (PCAP) FOR MAXILLARY ANTERIOR TEETH			
PCAP -Tooth type	Mesial side of PCAs	Mean Crown Lengths	Calculated PCAPs
PCAP: Maxillary Right Central Incisor	4.0570	10 mm	40 %
PCAP: Maxillary Right Lateral Incisor	3.0235	9 mm	33 %
PCAP: Maxillary Right Canine	1.8986	9.5 mm	19 %
PCAP: Maxillary Right First Premolar	1.4152	8 mm	17.5 %
PCAP: Maxillary Left Central Incisor	4.0570	10 mm	40 %
PCAP: Maxillary Left Lateral Incisor	2.8497	9 mm	31 %
PCAP: Maxillary Left Canine	2.0278	9.5 mm	21 %
PCAP: Maxillary Left First Premolar	1.4847	8 mm	17.5 %

Figure 3 demonstrated PCA and PCAP values suggested by us with decreasing trendline as we move away from midline. These simplified values are extracted from the data we collected and these can be used by clinicians as a general rule because they are easy to remember.
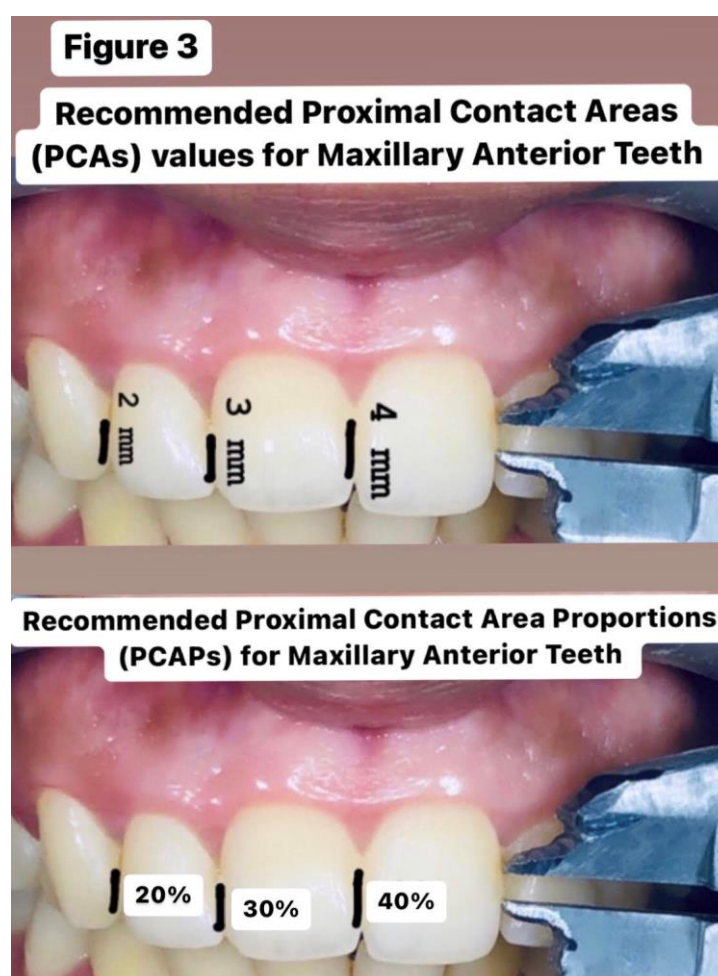
When paired sample t-test was performed to compare means of mesial and distal PCA dimensions of each individual tooth, p-value turned out to be significantly different on both sides. Mesial contacts were larger than distal contacts for all anterior teeth with decreasing trend from midline to laterally. (See table 3)

Table 3 : Comparison of Mean values of Mesial PCA and Distal PCA of each individual tooth								
Pairs	Paired Differences					t	Df	Sig. (2 tailed)
	Mean	S.D.	Std. Error Mean	95% Confidence interval of difference				
				Lower	Upper			
Pair 1 – Right Central Incisor's • Mesial PCA • Distal PCA	1.0335	.2021	.0143	1.0053	1.0616	72.29	199	.000
Pair 2 - Right Lateral Incisor's • Mesial PCA • Distal PCA	1.1248	.1595	.0112	1.1026	1.1470	99.72	199	.000
Pair 3 – Right Canine's • Mesial PCA • Distal PCA	.48345	.0760	.0053	.47284	.49405	89.92	199	.000
Pair 4 – Left Central Incisor's • Mesial PCA • Distal PCA	1.2073	.1830	.0129	1.1818	1.2328	93.26	199	.000
Pair 5 – Left Lateral Incisor's • Mesial PCA • Distal PCA	.82182	.3318	.0234	.77555	.86809	35.02	199	.000
Pair 6 – Left Canine's • Mesial PCA • Distal PCA	.54308	.3162	.0223	.49898	.58719	24.28	199	.000

DISCUSSION:

In the domain of restorative and aesthetic dentistry, accurate consideration of PCAs dimensions is essential for achieving functional and aesthetically pleasing outcomes during procedures such as crown placement. Well-defined PCAs contribute to occlusal stability, preventing issues like malocclusion and unwanted tooth movements, while also playing a critical role in averting potential gingival problems. The measurement of PCAs can be conducted through various methods, including both intraoral and extra oral approaches.

Extra oral methods involve the creation of stone casts obtained from alginate impressions of the participant's dentition (7, 16), standardized digital photographs (9, 17, 18) and periapical radiographs (8, 19) with subsequent measurements of PCAs are performed on these casts. However, these approaches come with inherent challenges. There is a risk of displacing papillae apically during the impression process, and the impressions themselves may be susceptible to distortion and the stone models produced may undergo expansion due to temperature changes, introducing variability in the measurements. Furthermore, the use of standardized digital photographs and radiographs may not fully capture the three-dimensional aspects of PCAs, leading to limitations in the accuracy of measurements. Contrastingly, intraoral methods, such as the one employed in this study by using a digital vernier caliper; involve direct measurements within the participant's oral cavity. This real-time approach allows for immediate assessment of the heights of proximal contacts, providing accurate data while minimizing potential distortions introduced by the casting process. Intraoral measurements, exemplified by the methodology in this study, offer a more direct and precise evaluation of PCAs, capturing the dynamic nature of the in vivo oral environment. Stappert et al.'s (7) study, which measured PCAs on stone models, acknowledged these challenges. In subsequent years, studies comparatively scrutinized both the extra oral and intraoral methods of PCA measurements. The findings of this comparative analysis revealed that the intraoral method, which involves direct measurements within the oral cavity, provided more accurate results than the extra oral method employed on stone casts (11, 16). The study's methodology aligns with subsequent research affirming the superior precision of intraoral methods compared to their extra oral counterparts.

In our study, the findings revealed that the PCAs dimension for central incisors (CI/CI) was maximized among the anterior dentition. Consistent with the findings of our study, literature showed that as the measurements progressed distally on either side, a gradual reduction in PCA dimensions was observed. This trend signifies that the PCAs tend to decrease gradually as one move away from

the midline in the maxillary dentition (6-8, 10, 11). Our study observed a consistent trend in PCAP, mirroring the pattern seen in PCAs measurement, with a gradual decrease from mesial to distal sites in the bilateral maxillary anterior dentition. This observation aligns with the findings of Stappert et al. (7), indicating a degree of agreement regarding the anteroposterior variation of PCAs and PCAPs in the maxillary anterior teeth. However, in contrast to another study, their results demonstrated higher values of PCAP for the lateral incisor to central incisor (LI/CI) and canine to first premolar (CA/PM) on either side (6). This discrepancy suggests potential variations in PCAP values across different studies, highlighting the importance of considering factors that may contribute to such differences, such as variations in study populations, methodologies, or sample characteristics.

CONCLUSION:
The research findings demonstrated a consistent bilateral decline in both mean PCAs and PCAPs value as we progressed away from the dental midline. This observation highlighted the central incisors as possessing the highest PCA dimensions. The implications emphasize the crucial importance of accounting for PCA dimensions in various dental procedures, specifically in restorative dentistry applications such as crown and veneer placement. This consideration is pivotal for attaining not only functional success but also achieving optimal aesthetic outcomes in dental restorations.

A potential limitation of our study lies in its focused examination only on the PCAs and PCAPs measurement of the MAT, it is important that the existing literature, showed that the authors in prior research explored various aspects, including dental papillae, crestal papilla, inter-proximal papilla dimensions, and investigated the relationships with periodontal parameters such as plaque index, gingival bleeding index, and clinical probing depth.

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