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Original Article

Comparison of Failure Rate between Temporary Anchorage Devices Placed in Infra-zygomatic Crest and Inter-radicular Bone during En-masse Retraction of Anterior Teeth of Maxilla

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ARTICLE INFO.

Received: April 28, 2026
Accepted: May 14, 2026

Volume: Vol-14, Issue-2, July 2026
DOI: https://doi.org/10.3329/jcds.v14i2.89552

Publisher: Sapporo Dental College, Dhaka, Bangladesh
Web: www.sdch.edu.bd
E-mail: jcds.sdc@gmail.com

Scan QR code to access your article on JCDS BanglaJOL index.

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ABSTRACT

Background: Temporary Anchorage Devices (TADs) play a crucial role in orthodontics by providing stable anchorage during en-masse retraction of maxillary anterior teeth. The choice of placement site can impact the stability and success of TADs. The purpose of the study is to compare the failure rates of TADs placed in the infra-zygomatic crest (IZC) and inter-radicular (IR) bone regions. **Objective:** To assess and compare the failure rates of TADs between the infra-zygomatic crest and inter-radicular bone during en-masse retraction of maxillary anterior teeth. **Methods:** A quasi-experimental study was conducted in the Department of Orthodontics, BMU, using 24 temporary anchorage devices (TADs) divided into two groups (12 TADs in each group) in 12 participants. Following a split-mouth design, in group A (IZC), TADs were placed in the infra-zygomatic crests and in group B (IR), TADs were placed in the molar-premolar inter-radicular sites. Each participants received 2 TAD, one in IZC and another in IR. The TADs were monitored at baseline and at monthly intervals over a three-month period to assess mobility or failure. A p-value of <0.05 was considered statistically significant. **Results:** No significant difference in failure rates between the infra-zygomatic crest group and the inter-radicular group was found. The overall failure rate was 29.2%. Failure rates were 33.3% in the infra-zygomatic crest group and 25.0% in the inter-radicular group.
Conclusion: Within the limits of this study's sample size and three-month observation period, both the infra-zygomatic crest and inter-radicular bone are viable and reliable sites for the insertion of TADs during en-masse retraction of the maxillary anterior teeth, as no statistically significant difference in failure rate was found between the two regions.

KEYWORDS: Anterior teeth of maxilla; Inter-radicular bone; Infra-zygomatic crest; Temporary Anchorage Device; Mini-screw; Mini-implant; Orthodontics; Orthodontic mini-screw.

INTRODUCTION

Since their initial clinical demonstration in 1983, which highlighted the potential for "absolute" anchorage control in humans, temporary anchorage devices (TADs) have significantly evolved in orthodontics [1]. The use of skeletal anchorage gained further popularity following Konami's 1997 publication, offering clinicians new avenues to manage complex tooth movements. In cases of pronounced anterior protrusion, extraction of premolars followed by anterior teeth retraction is often recommended to achieve optimal aesthetic outcomes. In particular, situations involving full-unit retraction of anterior teeth—such as in Class II malocclusion or Class I bimaxillary proclination—demand precise anchorage control to maintain posterior segments in position. Loss of molar anchorage can compromise the correction of anteroposterior discrepancies and alter facial vertical dimensions [2]. To mitigate such challenges, various anchorage reinforcement strategies have been developed. Conventional biomechanical approaches include extraoral devices, such as headgear, and intraoral devices, including trans-palatal arches or intermaxillary elastics. However, these methods may be inadequate when high anchorage is required, as their effectiveness often depends on patient compliance and sufficient supporting structures [3]. In contrast, TADs provide a reliable alternative by achieving mechanical stability through osseointegration or mechanical retention. Osseointegration ensures stability, whereas mobility is clinically indicative of implant failure. Orthodontic TADs can be categorized into osseointegrated and mechanically retained devices, with the latter achieving partial osseointegration over time [4]. Primary implant stability, determined at the time of insertion, is influenced by factors including bone thickness and quality, implant design, thread geometry, insertion torque, and loading conditions [5]. Subsequent secondary stability develops as new bone forms around the implant surface; however, inadequate primary stability can compromise secondary stability [6]. Clinical research has demonstrated that using TADs during en-masse retraction of maxillary anterior teeth significantly enhances posterior anchorage compared to conventional methods [7]. Both interradicular and infrazygomatic crest TADs demonstrate stability during such procedures, although reported failure rates differ: 28.1% for infrazygomatic crest TADs [8] and 24.5% for interradicular TADs [9]. In Bangladesh, research on TADs remains limited, despite their growing clinical application for anchorage reinforcement during en-masse retraction. There is a notable gap in understanding the comparative failure rates between infra-zygomatic and interradicular TADs in this population. Investigating this will provide critical evidence-based guidance to orthodontists regarding optimal TAD placement, ultimately improving treatment outcomes, minimizing complications, and enhancing patient satisfaction

METHODS

This quasi-experimental study was conducted in the Department of Orthodontics, Faculty of Dentistry, Bangladesh Medical University (BMU). Shahbagh, Dhaka, Bangladesh, over a period of one year following approval from the Institutional Review Board (IRB) of BMU. The study population comprised individuals pursuing fixed orthodontic therapy at the department. Participants aged 11–30 years who required extraction of maxillary first premolars followed by en-masse retraction of maxillary anterior teeth were considered eligible. A purposive sampling technique was employed, and 12 patients fulfilling the inclusion and exclusion criteria were selected. Each participant received two mini-implants, one on each side of the maxilla, resulting in a total of 24 temporary anchorage devices (TADs). The sample was split evenly according to insertion site into inter-radicular (n = 12) and infra-zygomatic crest (IZC) groups (n = 12). Sample size determination was based on the Krejcie and Morgan table. Participants with Class II Division 1 malocclusion or Class I bimaxillary proclination requiring extraction of maxillary first premolars and maximum anchorage for en-masse retraction were included. Only individuals with good periodontal health, no systemic illness, and treated using 0.018″ or 0.022″ Roth prescription appliances were selected. Patients with systemic disease, compromised periodontal status, history of anti-inflammatory drug therapy, smoking habit, pregnancy, or local bone pathology detected on orthopantomogram or cone-beam computed tomography (CBCT) were excluded. Bilateral maxillary first premolars were removed under aseptic conditions following the acquisition of written informed consent and assent. One week later, preadjusted edgewise appliances (Roth prescription, 0.018″ or 0.022″ slot) were bonded. Following completion of leveling and alignment, 0.017″×0.025″ stainless steel archwires (for 0.018″ slot) and 0.019″×0.025″ stainless steel archwires (for 0.022″ slot) were placed. Bone thickness at the planned insertion sites was assessed using cone-beam computed tomography (Orthophos S 3D; Dentsply Sirona, Bensheim, Germany). Images were acquired with a field of view of 12 × 10 cm and an isotropic voxel size of 75 µm in the standard-definition 3D mode, at a tube voltage of up to 90 kV, a tube current of 7–13 mA, and an exposure time of 2.2–14.9 s. All mini-implants were placed under aseptic conditions by a single experienced operator to minimize operator-related variability. Two distinct anatomical locations in the maxilla were used to insert mini-implants. In the inter-radicular group, mini-screws (8 mm × 1.4 mm) were inserted on the junction between attached gingiva and mucosa of buccal surface in between the maxillary second premolar and first molar at an angulation of 30°–40° to the occlusal plane. In the IZC group, mini-screws (10–12 mm × 2.0 mm) were placed at the inferior border of the zygomatic buttress, approximately 10–16 mm above the occlusal plane, at an angulation of 55°–70°. Orthodontic force of approximately 250 g was applied using elastic power chains or closed-coil springs, measured with a Dontrix gauge (American Orthodontics, Sheboygan, WI, USA), for en-masse retraction of the maxillary anterior teeth. Participants were evaluated at baseline and subsequently at one-month intervals for three successive months. Mini-implant failure was defined as having any degree of clinical mobility detected upon palpation. Data were entered and analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). The normality of continuous data was assessed using the Shapiro–Wilk test. Continuous variables (bone thickness), including comparisons between groups and between the success and failure subgroups, were compared using the independent-samples t-test. Categorical variables (failure rate, screw length, and screw material) were compared using the chi-square test. Survival of the mini-implants over the three-month period was analyzed using the Kaplan–Meier method, and the log-rank (Mantel–Cox) test was used to compare survival distributions between the two groups. A p-value < 0.05 was considered statistically significant. Ethical principles outlined in the Declaration of Helsinki were strictly followed, and confidentiality of participants was maintained throughout the study by assigning unique case identification numbers. Participation was voluntary, and no financial incentives were provided.

RESULTS

Table 1 compares the bone thickness between Group A (interradicular) and Group B (infra-zygomatic crest) regions. In Group A, the mean bone thickness was 10.27 ± 1.07 mm, while in Group B, it was 11.59 ± 1.07 mm. The difference between the two regions was statistically significant, with the infra-zygomatic crest exhibiting greater bone thickness compared to the interradicular area (p = 0.006). Table 2 presents the bone thickness in relation to TAD failure and success in both groups. In Group A, the mean bone thickness for failure cases (n = 3) was 10.10 ± 0.27 mm, while for success cases (n = 9) it was 10.34 ± 1.24 mm, with no statistically significant difference (p = 0.729). In Group B, failure cases (n = 4) had a mean bone thickness of 10.60 ± 1.08 mm, whereas success cases (n = 8) showed a significantly higher mean bone thickness of 12.08 ± 0.67 mm (p = 0.014), suggesting a significant association between greater bone thickness and TAD success in this region. Table 3 compares the overall failure rates of temporary anchorage devices between the interradicular and infra-zygomatic crest groups. In the interradicular group, 25.0% (n = 3) of TADs failed, whereas in the infra-zygomatic crest group, 33.3% experienced failure. In both groups, the overall failure rate was 29.2%. Interradicular placements achieved a 75.0% success rate, while the IZC group recorded a 66.7% success rate. The comparison was not statistically significant (p = 0.653), suggesting that there was no significant difference in failure rates between the two TAD insertion sites despite the differences in failure and success rates between the two groups.

Kaplan–Meier survival analysis over the three-month observation period showed an overall mean survival time of 2.859 months (95% CI: 2.729–2.988). The mean survival time was 2.938 months (95% CI: 2.817–3.058) in the inter-radicular group and 2.781 months (95% CI: 2.561–3.002) in the infra-zygomatic crest group. The log-rank (Mantel–Cox) test revealed no statistically significant difference in survival distribution between the two sites, although the result approached the threshold of significance ($\chi^2 = 3.556$, df = 1, $p = 0.059$). With respect to the timing of failure, no TAD became mobile immediately upon loading, as all mini-implants were clinically stable at baseline. Three of the seven failures were detected at the first-month review (one inter-radicular and two infra-zygomatic crest) and, occurring within approximately four weeks of loading, were regarded as early failures reflecting a loss of primary stability. The remaining four failures occurred later and were considered consistent with a loss of secondary stability: two infra-zygomatic crest TADs failed at the second-month review and two inter-radicular TADs failed at the third-month review. Early (primary-stability) and delayed (secondary-stability) failures therefore accounted for three and four of the seven failures, respectively. Notably, all infra-zygomatic crest failures occurred within the first two months, whereas both late inter-radicular failures were recorded at the third month.

Table-1: Comparison of Bone Thickness between Group A (Inter-radicular) and Group B (Infra-zygomatic crest) regions (N=24)

	Group A (Inter-radicular) Mean ± SD	Group B (Infra-zygomatic crest) Mean ± SD	p-value
Bone thickness (mm)	10.27±1.07	11.59±1.07	0.006*

Table-2: Comparison of Bone Thickness between Failure and Success Cases of TADs Placed in group A (Inter-radicular) and group B (Infra-zygomatic crest) Regions (N=24)

	Failure Mean ± SD	Success Mean ± SD	p-value
Group A (Inter-radicular)	n=3 10.1±0.27	n=9 10.34±1.24	0.729
Group B (Infra-zygomatic crest)	n=4 10.60±1.08	n=8 12.08±0.67	0.014*

Table-3: Comparison of Overall Failure Rates of TADs between Group A (Inter-radicular) and Group B (Infra-zygomatic Crest) Regions (N=24)

	Group A (Inter-radicular) No. (%)	Group B (Infra-zygomatic crest) No. (%)	p-value
Failure	3(25.0%)	4(33.3%)	0.653
Success	9(75.0%)	8(66.7%)	

Table 4: Timing of TAD failures and corresponding stability phase (n = 7 failures)

Time of detection	**Stability phase**	**Inter-radicular, n**	**Infra-zygomatic crest, n**	**Total, n**
Immediately on loading (baseline)	Primary	0	0	0
First-month review	Primary (early)	1	2	3
Second-month review	Secondary (delayed)	0	2	2
Third-month review	Secondary (delayed)	2	0	2
Total		**3**	**4**	**7**

DISCUSSION

This study was conducted to determine if a significant difference in failure rates exists between IZC and IR, mini-implants used for maxillary en-masse retraction. The findings demonstrated no statistically significant difference between the two sites, with an overall failure rate of 29.2%. These results indicate that both IZC and IR regions offer reliable skeletal anchorage, confirming their efficacy when proper orthodontic biomechanics are implemented. These findings are consistent with [10], who reported comparable success rates between IZC and IR mini-implants during en-masse retraction. Although observed a slightly lower success rate in IZC mini-implants, the difference was minimal. Variations among studies may be attributed to differences in patient-related factors, operator skill, loading protocols, and oral hygiene status. Bone characteristics remain important for TAD stability. In the present study, overall bone thickness did not significantly influence failure rates when both sites were considered together. This aligns with [4, 11] who emphasized that cortical bone thickness, rather than total bone thickness, plays a more decisive role in mini-implant stability. However, site-specific analysis showed that bone thickness significantly influenced success in the IZC region. Successful IZC TADs were associated with greater mean bone thickness compared to failed cases. Similar findings were reported by [12] who linked reduced infra-zygomatic bone thickness with increased failure rates. In contrast, IR TADs showed no significant association between bone thickness and failure rate, supporting the observations of [13] who suggested that insertion precision and micro-movement control are more critical in thinner inter-radicular bone. Moreover, [3] highlighted that insertion technique, bone quality, and operator experience may be more influential than anatomical site alone. The use of appropriate insertion angles and adequate torque in both regions may explain the comparable performance observed in this study, as optimized insertion parameters enhance primary stability regardless of site [5]. No significant difference in failure rate was observed between stainless steel and titanium alloy TADs. This finding is consistent with previous reports indicating that implant material is not a primary determinant of success, provided correct placement and loading protocols are followed [14]. Similarly, implant length was not significantly associated with failure rate in this study. Previous studies have also reported that mini-implant length alone does not significantly influence clinical success when sufficient cortical engagement is achieved [8, 4]. Overall, the present findings support the concept that TAD success during en-masse retraction is multifactorial. While anatomical site and bone thickness—particularly in the IZC region—may contribute to stability, factors such as cortical bone quality, insertion technique, loading mechanics, and operator expertise appear to play a more decisive role in determining clinical outcomes.

LIMITATIONS

This study has several limitations that should be considered when interpreting its findings. First, the sample comprised only 24 TADs in 12 participants. Although the split-mouth design controlled for inter-individual biological variation, this sample size limited the statistical power available to detect modest between-site differences in failure rate (25.0% versus 33.3%). The non-significant comparison of failure rates ($p = 0.653$) should therefore be interpreted with caution, as it does not exclude the possibility that a genuine difference exists which the present study was underpowered to detect, that is, a Type II error. This interpretation is reinforced by the survival analysis, in which the log-rank comparison approached significance ($p = 0.059$). Larger, preferably multi-centre, cohorts are required to confirm whether the two insertion sites are truly equivalent in failure rate.

Second, the subgroup comparisons of bone thickness between failed and successful TADs (Table 2) were based on small cohorts, most notably the inter-radicular failure subgroup ($n = 3$ versus $n = 9$). These comparisons, performed using the independent-samples t-test, should therefore be regarded as exploratory, as the limited subgroup sizes reduce the precision of the estimates and the statistical power of the analysis. The significant association between greater bone thickness and success observed in the infra-zygomatic crest group thus warrants confirmation in larger samples before firm conclusions are drawn.

Third, the observation period was limited to three months. Although en-masse retraction of the maxillary anterior teeth frequently extends beyond one year, mini-implant stability was monitored for three months only. This window adequately captures early failures, which relate predominantly to inadequate primary stability and typically occur soon after loading; however, it may not reflect secondary stability or the risk of late failures arising from prolonged loading, peri-implant inflammation, and changes in oral hygiene over the complete duration of treatment. The failure rates reported here should consequently be regarded as early-phase estimates. Additional limitations include the single-center design with purposive (non-probability) sampling, which may introduce selection bias and limit generalizability; placement of all mini-implants by a single operator, which minimized inter-operator variability but restricts applicability to operators of differing experience; and the measurement of total bone thickness on CBCT without separate assessment of cortical bone thickness or bone density, despite the recognized importance of cortical quality for primary stability. Finally, several potentially influential factors, including insertion torque, soft-tissue thickness, thread design, and the self-drilling versus self-tapping nature of the screws, were not quantified or analyzed.

CONCLUSION

Within the limitations of this study, namely its modest sample size and three-month observation period, both the infra-zygomatic crest and inter-radicular bone appear to be viable and reliable sites for the placement of TADs during en-masse retraction of the maxillary anterior teeth, as no statistically significant difference in failure rate was observed between the two regions. These findings should be confirmed in larger, longer-term studies before firm clinical recommendations are made.

ACKNOWLEDGEMENT

All praise is due to Almighty Allah for granting me the strength and opportunity to complete this work. I sincerely express my deepest gratitude to my respected supervisor, Prof. Dr. Gazi Shamim Hassan Sir, for his invaluable guidance, continuous support, and constructive feedback throughout this study. I am also thankful to all teachers and colleagues who provided assistance and encouragement. Special appreciation goes to the participants of this research for their cooperation. Finally, I am profoundly grateful to my family for their unwavering love, patience, and constant support.

FUNDING: This study was supported by Bangladesh Medical University (BMU).

CONFLICT OF INTEREST: The authors declare that there is no conflict of interest regarding the publication of this paper.

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HOW TO CITE

Khondakar AFMAS, Zaman MSU, Haque TA, Ghosh R, Hassan GS. Comparison of Failure Rate between Temporary Anchorage Devices Placed in Infra-zygomatic Crest and Inter-radicular Bone During En-masse Retraction of Anterior Teeth of Maxilla. J. Contemp. Dent. Sci. [Internet]. [cited 2026 Jul. 14];14(2):27-31. Available from:
https://www.banglajol.info/index.php/JCDS/article/view/89552

JCDS -ISSN: 2305-9664