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Original Article

Dentistry Section

Comparison of Amount of Intrusion and Extent of Periapical Root Resorption with Temporary Anchorage Devices and Connecticut Intrusion Arch in Adult Population: A Prospective Interventional Study

JAPNEET KAUR KAISER[1], RANJIT KAMBLE[2], SRUSHTI ATOLE[3], NANDLAL TOSHNIWAL[4], RUCHIKA PANDEY[5]

ABSTRACT

Introduction: Deep bite is a common vertical malocclusion often requiring maxillary incisor intrusion for correction, especially in adult patients. Two widely used methods for intrusion are Temporary Anchorage Devices (TADs) and the Connecticut Intrusion Arch (CIA). While both are effective in achieving intrusion, they may differ in their biological impact, particularly in terms of root resorption. Given the limited clinical evidence comparing these two techniques in terms of both efficacy and safety, the present study was undertaken to provide a Cone Beam Computed Tomography (CBCT)-based evaluation to guide clinical decision-making.

Aim: To evaluate and compare the amount of intrusion and the extent of periapical root resorption of maxillary anterior teeth using TADs and CIA in adult patients assessed using CBCT.

Materials and Methods: The present prospective interventional study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Sharad Pawar Dental College, Sawangi (Meghe), Wardha, Maharashtra, India, from March 2022 to January 2023. A total of 20 post-pubertal patients diagnosed with deep bite were selected based on defined inclusion criteria: increased overbite >3 mm and reduced lower anterior facial height. The selected patients were randomly divided into two groups (n=10 each): Group I (TADs) and Group II (CIA). All patients were bonded with 0.022" MBT (McLaughlin, Bennett, and Trevisi) brackets and underwent standard levelling and alignment. An intrusion force of 100 g was applied to the anterior teeth segment for six months. CBCT scans were obtained at four-time intervals- T0 (baseline), T1 (1 month), T2 (3 months), and T3 (6 months). Intrusion was measured as the perpendicular distance from the incisal edge to the palatal plane. Root resorption was assessed by comparing root length changes from T0 to T3. Statistical analysis was performed using SPSS Version 27.0. Data were expressed as mean±Standard Deviation (SD). The Shapiro-Wilk test was used to assess normality, and independent sample t-tests were applied to compare groups. A p-value <0.05 was considered statistically significant.

Results: Both TADs and CIA produced comparable amount of maxillary anterior intrusion, with no statistically significant differences between groups at any time point (p>0.05). However, root resorption in central incisors was significantly higher in the TAD group (1.21±0.25 mm for 11, 1.19±0.23 mm for 21) than in the CIA group (0.72±0.52 mm and 0.84±0.44 mm, respectively), with p-values of 0.016 and 0.041. No significant differences were observed in lateral incisors.

Conclusion: TADs and CIA are equally effective in achieving maxillary anterior intrusion. However, TADs are associated with greater root resorption in central incisors. CIA may be a safer alternative when root preservation is a clinical priority.

Keywords: Adult orthodontics, Cone-beam computed tomography, Deep bite, Orthodontic anchorage procedures

INTRODUCTION

Deep bite, a type of vertical malocclusion, is defined as an excessive overlap of the maxillary anterior teeth over the mandibular incisors. It can be classified into skeletal and dentoalveolar forms, or further categorised as true, pseudo, incomplete, and complete deep bite based on aetiology and clinical presentation [1]. It typically results from a combination of innate skeletal patterns, such as a short lower facial height, flat mandibular plane, and square gonial angle, or acquired dental compensations including supraeruption of incisors and infraeruption or loss of posterior teeth. If left untreated, deep bite may lead to various functional and pathological consequences, including incisal wear, periodontal trauma, difficulty in mastication, speech problems, Temporomandibular Joint Disorders (TMD), and soft-tissue trauma [2].

Correction of deep bite is crucial not only for functional rehabilitation but also for long-term occlusal stability and aesthetic enhancement. Among the various treatment strategies available, anterior teeth intrusion is one of the most reliable and frequently employed methods, particularly in adult patients where vertical growth modification is not feasible. The biomechanics of intrusion require precise force application through the tooth's centre of resistance to avoid undesired tipping or flaring. This mandates careful selection of force magnitude, direction, and anchorage control [3].

Various appliances have been developed to achieve controlled incisor intrusion, including the CIA and TADs [4,5]. The CIA, derived from Burstone's principles of segmental mechanics, is constructed using heat-activated Nickel-Titanium (NiTi) alloys that deliver light, continuous forces over time. This intrusion arch is often preferred for its ease of activation, patient comfort, and reduced need for frequent

adjustments. The design of the CIA also allows for correction of minor occlusal discrepancies and molar tip-back, making it a versatile tool in bioprogressive therapy [4].

On the other hand, TADs represent a modern skeletal anchorage system that enables absolute control without relying on adjacent teeth. Mini-screws are commonly placed in the interradicular space between the lateral incisors and canines after levelling and alignment, allowing for direct force application to the anterior segment. Titanium or titanium-alloy mini-screws are typically used, and their non-osseointegrating design allows for easy insertion and removal. TADs have gained popularity due to their efficiency, minimal patient compliance requirement, and ability to produce pure intrusion without reciprocal extrusion of molars [6].

Despite their advantages, both modalities pose a risk of Orthodontically Induced Root Resorption (OIRR), particularly in the maxillary anterior region, which is most susceptible due to root morphology and thin labial cortical bone. OIRR is a multifactorial phenomenon influenced by patient-related factors (such as age, sex, systemic health, and tooth type) and treatment-related factors (including type of force, duration, and appliance used). Excessive or prolonged force application can lead to significant periapical root resorption, compromising tooth longevity and treatment outcomes. While utility arches and TADs are both effective in achieving intrusion, comparative data on their influence on root resorption remain limited [7].

High-resolution CBCT has emerged as a superior imaging modality in orthodontics for assessing root morphology and quantifying root resorption three-dimensionally with minimal distortion and high accuracy, overcoming the limitations of conventional radiographs [8]. Given the paucity of clinical evidence evaluating both the amount of intrusion and the extent of periapical root resorption associated with CIA and TADs, this CBCT-based study was undertaken to assess and compare the biomechanical efficiency and biological safety of these two commonly used intrusion techniques in adult patients with deep bite.

The primary aim of the study was to evaluate and compare the amount of intrusion and the amount of periapical root resorption of maxillary anterior teeth using TADs and the CIA, assessed with CBCT.

The outcomes of the present study aimed to provide clinicians with a clearer understanding of the relative advantages and risks associated with each method, facilitating evidence-based appliance selection in clinical practice.

Null Hypothesis (H_0): There is no significant difference in the amount of intrusion or root resorption of maxillary anterior teeth between TADs and CIA.

Alternate Hypothesis (H_1): There is a significant difference in the amount of intrusion and/or root resorption of maxillary anterior teeth between TADs and CIA.

MATERIALS AND METHODS

The present prospective interventional study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Sharad Pawar Dental College, Sawangi-Meghe, Wardha, Maharashtra, India, in collaboration with the Department of Oral Medicine and Radiology, from March 2022 to January 2023. After obtaining clearance from the Institutional Research Ethics Committee of Datta Meghe Institute of Higher Education and Research (Deemed to be University), the ethical approval letter was obtained with reference number- DMIMS (DU)/IEC/2022/748.

Inclusion criteria:

- Patients with an increased overbite (i.e., more than 3mm);
- Patients with a reduced lower anterior facial height, defined as less than 68.6±3.8 mm in males and less than 61.3±3.3 mm in females (i.e., Anterior Nasal Spine (ANS) to Gnathion measurement below 68.6±3.8 mm for males and below 61.3±3.3 mm for females) [9];
- Patients of post-pubertal age (16-25 years) were included in the study. Skeletal maturity was confirmed based on chronological age, complete eruption of permanent second molars, and clinical signs of completed growth.

Exclusion criteria:

- Patients with chronic or relapsing periodontal disease;
- Patients with Root Canal (RC) treated anteriors;
- Individuals with any systemic diseases;
- Patients with previous orthodontic treatment;
- Any missing anterior or molars in maxilla.

Sample size calculation: Sample size formula for difference between two means [10]:

$n=(Z\alpha + Z\beta)\ 2\ (\sigma 12 + \sigma 22\ /K)$

Δ

Where;

$Z\alpha$ is the level of significance at 5%. i.e.,

95% confidence interval=1.96

$Z\beta$ is the power of test=80%=0.84

$\sigma 1$=SD of central incisor in mini implant group=1.095

$\sigma 2$=SD of central incisor is utility arch group=0.742

Δ=Difference between two means=23.55-22.28=1.27

K=1

n=(1.96+0.84)2 (1.0952+0.742/1)

1.272

=8.59

=> n=10 patients needed in each group

Study Reference: Bhat M et al., [2].

Power of test: 80%

Level of significance: 5%

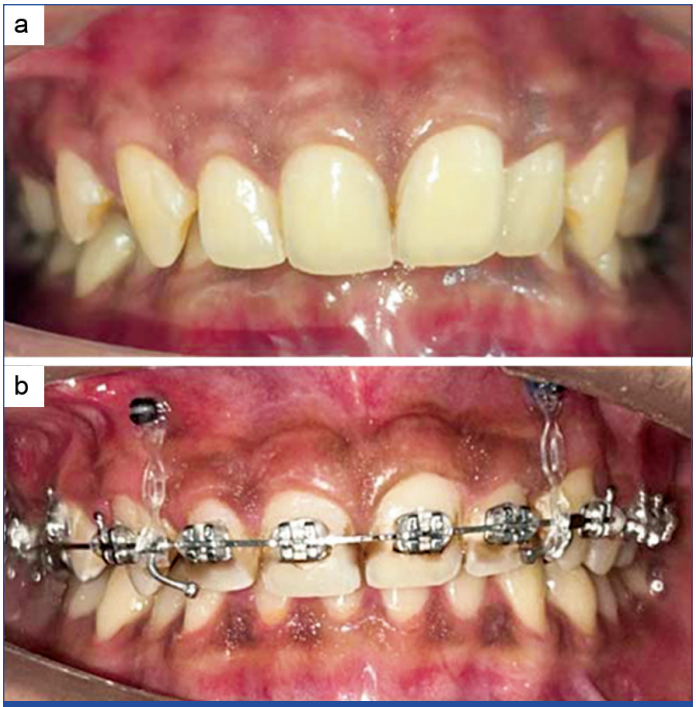
Software Used: SPSS 27.0 Version GraphPad Prism 7.0 Version.

Study Procedure

A total of 66 post-pubertal patients reporting to the Department of Orthodontics and Dentofacial Orthopaedics, Wardha, Maharashtra, India, were initially screened through intraoral examination, which included visual inspection of overbite depth, assessment of incisor display, molar and canine relationships, and evaluation of oral hygiene status and periodontal health using a mouth mirror and probe under proper illumination. Based on defined inclusion and exclusion criteria, 20 patients were finally selected through random sampling for the present prospective interventional study. Written informed consent was obtained from all participants after explaining the nature, purpose, and procedures of the study, including the use of CBCT imaging and the planned orthodontic interventions. The selected patients were randomly divided into two groups using the chit method:

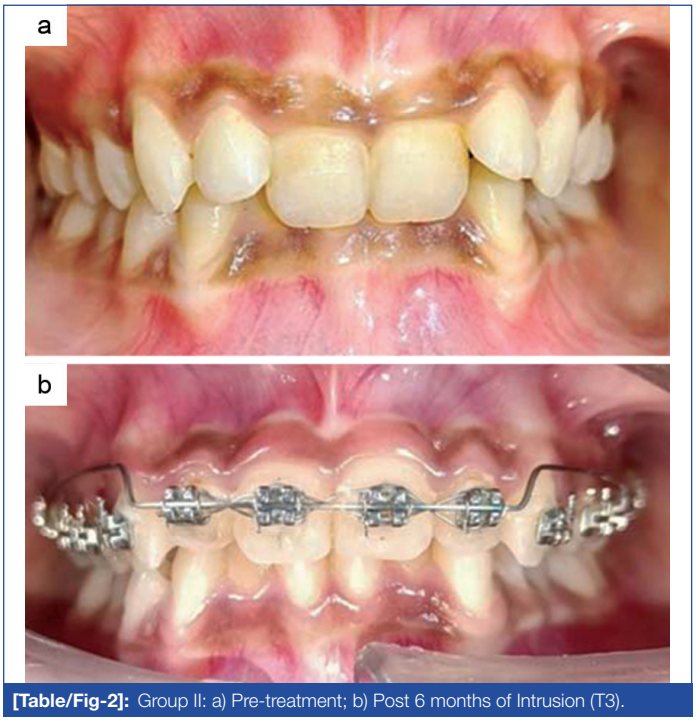
- Group I (n=10): Treated with Temporary Anchorage Devices (TADs)
- Group II (n=10): Treated with Connecticut Intrusion Arch (CIA)

All subjects were bonded with 0.022" MBT brackets and underwent standard levelling and alignment using a NiTi and stainless-steel wire sequence. Following this, TADs (1.5 mm × 8 mm titanium mini-implants, SK Surgicals, Pune, Maharashtra) were placed interradicularly between the maxillary lateral incisors and canines in Group I [Table/Fig-1].



[Table/Fig-1]: Group I: a) Pre-Treatment; b) Post 6 months of intrusion (T3).

while Group II received preformed 0.016"×0.022" NiTi CIA(Ormco Corporation, Orange, CA, USA) [Table/Fig-2].



[Table/Fig-2]: Group II: a) Pre-treatment; b) Post 6 months of Intrusion (T3).

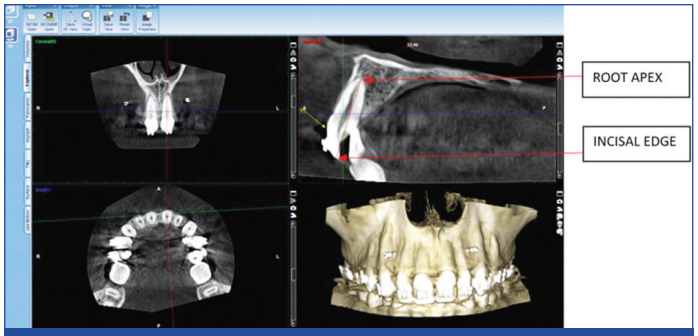
A constant force of 100g was applied to the maxillary anterior teeth in both groups for six months, measured with a Dontrix gauge [1].

CBCT scans were taken using the Planmeca ProMax machine at four time points:

- T0: Post levelling and alignment, before intrusion;
- T1: After 1 month of application of intrusive forces;
- T2: After 3 months of application of intrusive forces;
- T3: After 6 months of application of intrusive forces.

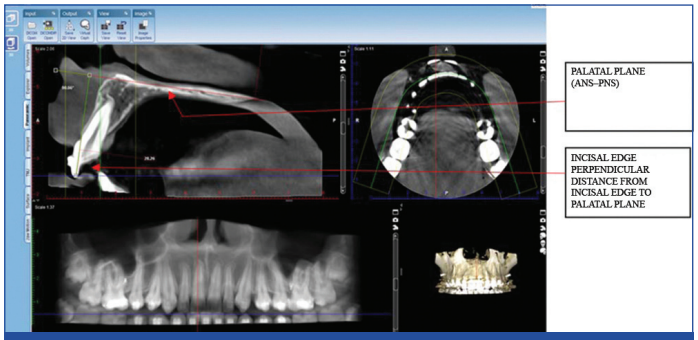
Root resorption measurement: Root length (incisal edge to apex) was measured at each time point. The amount of root resorption was calculated by subtracting the T3 root length from the T0 baseline [Table/Fig-3].

Intrusion measurement (mm): Intrusion was assessed by measuring the perpendicular distance from the incisal edge of



[Table/Fig-3]: Evaluation of tooth length for root resorption.

maxillary central and lateral incisors to the palatal plane on CBCT images using PlanmecaRomexis Viewer software. While no prior published study was located that identically describes this measurement protocol using Romexis Viewer, similar measurement methods have been used in CBCT-based studies [11], and the Romexis software has been used in volumetric CBCT analyses in recent literature [Table/Fig-4] [12].



[Table/Fig-4]: Evaluation of intrusion. CBCT image showing measurement of maxillary incisor intrusion as the perpendicular distance from the incisal edge to the palatal plane (ANS-PNS).

All data were digitised and analysed by a calibrated examiner to compare the amount of intrusion and root resorption between both groups. Intra-examiner reliability was assessed by repeating measurements on 20% of the samples after a two-week interval, and reliability was confirmed using the Intraclass Correlation Coefficient (ICC).

STATISTICAL ANALYSIS

Both descriptive and inferential statistical analyses were performed. Data were expressed as mean and standard deviation. The normality of continuous variables was assessed using the Shapiro-Wilk test. Since the data followed a normal distribution, parametric tests were applied for further analysis. Independent sample t-tests were utilised to evaluate mean differences. A significance level of $p<0.05$ was considered statistically significant. All analyses were conducted using Statistical Package for the Social Sciences (SPSS), Version 27.0 (IBM Corporation, Chicago, USA).

RESULTS

Root resorption: The amount of root resorption was assessed by measuring the change in root length of maxillary central and lateral incisors from baseline (T0) to six months post-intrusion (T3) [Table/Fig-5].

In Group I (TADs), a greater degree of root resorption was observed compared to Group II (CIA), particularly in the maxillary central incisors. The mean root resorption for the maxillary right central incisor (tooth 11) was 1.21±0.25 mm in Group I, significantly higher than 0.72±0.52 mm in Group II ($p=0.016$). Similarly, for the maxillary left central incisor (tooth 21), Group I showed a mean resorption of 1.19±0.23 mm, significantly greater than 0.84±0.44 mm in Group II ($p=0.041$).

In contrast, the resorption observed in the maxillary lateral incisors (teeth 12 and 22) did not differ significantly between the two groups. For tooth 12, the mean resorption was 0.61±0.08 mm in Group I and 0.68±0.39 mm in Group II (p=0.585). For tooth 22, it was 0.66±0.23 mm in Group I and 0.68±0.42 mm in Group II (p=0.888).

These findings indicate that TAD-based intrusion is associated with significantly more root resorption in central incisors compared to CIA, while lateral incisors were similarly affected in both groups.

Amount of Intrusion: The amount of intrusion was measured by evaluating the vertical movement of the maxillary anterior teeth from the incisal edge to the palatal plane at four-time intervals: T0 (baseline), T1 (1 month), T2 (3 months), and T3 (6 months). The amount of intrusion was calculated as the change in measurements over time (mm) [Table/Fig-6].

In Group I (TADs), the mean intrusion progressed from 25.34±3.78 mm at T0 to 22.21±3.44 mm at T3. In Group II (CIA), the corresponding values ranged from 23.67±3.08 mm at T0 to 22.13±3.15 mm at T3. Although Group I exhibited a slightly greater amount of intrusion over time compared to Group II, the difference was not statistically significant at any of the measured time points (T0 to T3), with p-values>0.05 consistently. These results suggest that both TADs and CIA are comparably effective in achieving maxillary anterior intrusion over six months, with no statistically significant difference in the overall amount of intrusion between the two groups.

DISCUSSION

Root resorption is a well-documented complication of orthodontic treatment, influenced by both patient-related (age, sex, root morphology, systemic conditions) and treatment-related factors (force magnitude, duration, type of movement, and appliance used). Inflammatory root resorption, the most common type during orthodontics, is associated with prolonged stimulation, often progressing from transient damage to progressive loss of root structure. External factors such as dense cortical bone contact and abnormal habits like tongue thrust or nail-biting may further aggravate resorption [13].

Age plays a significant role-adults are more susceptible due to reduced vascularity and cellular activity in the periodontal ligament and bone [14]. Additionally, teeth with fully developed roots show higher resorption risk compared to those with incomplete root formation. Females also appear more prone to root resorption, possibly due to differences in root maturity or hormonal influences. Root shape, particularly pipette-or blunt-shaped roots, is also linked with increased susceptibility [15].

Among tooth movements, intrusion and torque are most strongly associated with root resorption, especially in maxillary incisors, which are frequently involved in aesthetic and functional corrections. Although recommended forces for intrusion range from 25 g per tooth to 125g, excessive force can paradoxically decrease intrusion efficiency while increasing the risk of root damage [1,16]. Kalra V recommended that a force of 125g is effective for the intrusion of the anterior teeth. The K-SIR archwire exerts about 125g of intrusive force on the anterior segment [16].

Endodontically treated teeth exhibit inconsistent findings in the literature, with some studies suggesting reduced susceptibility to resorption due to altered cellular responses [17-19]. Denser alveolar bone has also been linked to greater root resorption during orthodontic force application [20].

Radiographic assessment of root resorption poses challenges, especially with conventional Two-dimensional (2D) techniques that cannot reliably detect buccal and lingual resorption. CBCT has emerged as a superior diagnostic tool, providing three-dimensional, distortion-free visualisation of root changes. Alamadi E et al., suggested CBCT is the most accurate technique when measuring and scoring root resorption, in his study with an aim to compare CBCT and conventional radiographs such as, periapical radiographs and panoramic radiographs in diagnosing the extent of root resorption [21].

Given the limited comparative evidence on the effects of TADs vs. CIA on root resorption and intrusion efficiency, this study aimed to evaluate both parameters using CBCT. By analysing maxillary anterior teeth intruded with controlled forces via these two modalities, this study contributes clinically relevant data toward safer and more effective deep bite correction in adult patients.

Root Resorption

However, significant differences emerged in root resorption. Central incisors treated with mini-implants exhibited greater

Teeth	Group	N	Mean	SD	SE	MD	95% CI	t-value	p-value#
11	I	10	1.21	0.25	0.08	0.49	0.10-0.88	2.650	0.016†
	II	10	0.72	0.52	0.16				
21	I	10	1.19	0.23	0.07	0.35	0.01-0.68	2.200	0.041†
	II	10	0.84	0.44	0.14				
12	I	10	0.61	0.08	0.02	-0.07	-0.33-0.19	-0.556	0.585
	II	10	0.68	0.39	0.12				
22	I	10	0.66	0.23	0.07	-0.02	-0.34-0.30	-0.143	0.888
	II	10	0.68	0.42	0.13				

[Table/Fig-5]: Comparison of mean difference in root resorption (mm) from T0 to T3 in maxillary anteriors between the two groups. (N=Sample size, 10 per group).
#p-value derived from independent sample t-test; †significant at p<0.05; SE-Standard error; MD-Mean difference

Timeline	Group	N	Mean	SD	SE	MD	95% CI	t-value	p-value#
T0	I	10	25.34	3.78	1.19	1.66	-1.58-4.90	1.077	0.296
	II	10	23.67	3.08	0.97				
T1	I	10	24.54	3.63	1.14	1.47	-1.69-4.65	0.975	0.343
	II	10	23.06	3.10	0.98				
T2	I	10	23.29	3.40	1.07	0.71	-2.36-3.78	0.487	0.632
	II	10	22.58	3.13	0.98				
T3	I	10	22.21	3.44	1.08	0.07	-3.02-3.18	0.052	0.959
	II	10	22.13	3.15	0.99				

[Table/Fig-6]: Comparison of perpendicular distance from incisal edge to palatal plane (mm) in maxillary anterior teeth between the two groups.
#p-value derived from independent sample t-test

resorption (around 1.2 mm) compared to those intruded using a conventional intrusion arch (~0.8 mm), consistent with previous clinical observations. In a randomised CBCT-based trial, intrusion using mini-implant anchorage resulted in significantly higher root resorption compared to CIA mechanics [22].

Interestingly, the findings for lateral incisors showed no significant difference between the two modalities, suggesting that anatomical positioning may influence susceptibility to root resorption.

Bhat M et al., conducted a study comparing root resorption associated with the use of utility arches and miniscrews for the correction of anterior deep bite. Their findings revealed that the miniscrew group exhibited significantly greater root resorption than the utility arch group [2]. The results of the present study are consistent with these findings, further supporting the conclusion that TADs are associated with increased root resorption compared to CIA during maxillary incisor intrusion.

Intrusion Efficiency

The results indicated that both TADs and CIA achieved similar amount of intrusion over six months, with no statistically significant differences observed between the groups. A study conducted by Alam F et al., to evaluate the amount of intrusion and associated root resorption caused by Burstone intrusion arch and Mini implants, concluded that no significant difference was found in mean incisor intrusion. Alam F et al., concluded that intrusion with both the intrusion systems using appropriate intrusive forces is effective in opening the bite with slightly more external apical root resorption in the mini-implant group [22].

These consistent outcomes highlight important clinical trade-offs:

- TADs provide slightly faster and purer intrusion, minimising tipping, but increase the risk of root shortening, particularly in central incisors.
- CIA, while marginally less efficient in intrusion, appear gentler on root structure, perhaps owing to reduced force magnitude per tooth and different load distributions.

Such insights advocate for a personalised approach. In cases where intrusion is minimal or root health is a concern, CIA might offer a safer option. Conversely, when maximal bite correction is needed and root morphology allows, TADs remain valuable.

Based on the results, the null hypothesis was accepted for intrusion, as no significant difference was observed between the TAD and CIA groups ($p>0.05$). However, it was rejected for root resorption, as a statistically significant difference was observed in the central incisors, with higher values in the TAD group ($p<0.05$).

Although the published research protocol had included gender-based subgroup analysis for evaluating the amount of intrusion and root resorption at different time intervals, this could not be carried out in the present study [23]. The subgroup size (5 males and 5 females in each arm) was too small to allow statistically valid comparisons. Conducting such stratified analysis would have compromised statistical power and reliability, potentially leading to misleading conclusions. Therefore, after consultation with the statistician, the analysis was limited to overall group comparisons between CIA and TADs, irrespective of gender. This deviation from the published protocol is acknowledged to maintain transparency and ensure that the findings presented are both robust and clinically meaningful.

Limitation(s)

The present study had certain limitations that should be acknowledged. Although the present study employed a priori sample size calculation to ensure adequate statistical power, the relatively modest number of participants may limit the generalisability of the findings to larger and more diverse populations. Although gender-based comparisons were proposed in the initial research protocol, they were not conducted due to insufficient subgroup sizes, limiting the ability to assess sex-related differences in treatment outcomes. Additionally, the CBCT measurements were not blinded, which may introduce measurement bias. Several potential confounding variables, such as initial incisor inclination, individual variations in bone density, and occlusal forces, were not separately analysed, though they could have influenced both the amount of intrusion and the extent of root resorption. Lastly, the present study was conducted in a single institutional setting, which may limit the external validity of the results when applied to broader populations.

CONCLUSION(S)

Both TADs and CIA were effective in achieving maxillary incisor intrusion, with no significant difference in the amount of intrusion. However, TADs resulted in significantly greater root resorption in central incisors compared to CIA. While TADs offer efficient intrusion, CIA may be a safer alternative when preservation of root structure is a priority.

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PARTICULARS OF CONTRIBUTORS:
1. Postgraduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Higher Education and Research, Sawangi (Meghe), Wardha, Maharashtra, India.
2. Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Higher Education and Research, Sawangi (Meghe), Wardha, Maharashtra, India.
3. Postgraduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Higher Education and Research, Sawangi (Meghe), Wardha, Maharashtra, India.
4. Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, Pravara Institute of Medical Sciences, Loni, Maharashtra, India.
5. Postgraduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Higher Education and Research, Sawangi (Meghe), Wardha, Maharashtra, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Srushti Atole,
Postgraduate Student, Department of Orthodontics and Dentofacial Orthopaedics,Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Higher Education and Research, Sawangi (Meghe), Wardha-442107, Maharashtra, India.
E-mail: srushtiatole@gmail.com

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