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Orthodontically induced external apical root resorption of mandibular anteriors after use of Forsus™ and Advansync™ 2- A CBCT study

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ABSTRACT

Background- Class II malocclusion is a common skeletal discrepancy which may be managed through various treatment modalities, including fixed functional appliances like AdvanSyncTM and ForsusTM FRD, widely used for non-compliant patients . However, one of the significant concerns associated with these appliances wasorthodontically induced external apical root resorption (OIEARR).This study aimed to evaluate and compare the degree of orthodontically induced external apical root resorption in skeletal Class II patients treated with Forsus™ and AdvanSync™ 2 fixed functional appliances using Cone Beam Computed Tomography (CBCT).

Materials and Methods-The study involved 20 patients with skeletal Class II malocclusions (true mandibular retrusion), divided into two groups of 10 each. CBCT scans were taken before and after 6–12 months of fixed functional treatment with AdvanSync™ 2 (Group I)and Forsus™ (Group II) to assess root resorption and tooth inclination changes. Statistical analysis was performed using the Wilcoxon signed-rank test and the Mann–Whitney U test.

Results- Root resorption was observed in all patients, with Forsus™ demonstrating a significantly higher mean root resorption compared to AdvanSync™ 2. The highest values were recorded for mandibular canines, with statistically significant differences between the two groups. Additionally, both appliances caused an increase in mandibular incisor proclination, but Forsus™ resulted in greater inclination changes compared to AdvanSync™ 2.

Conclusion-AdvanSync™ 2 and Forsus™ are both effective in treating skeletal Class II malocclusion by facilitating mandibular advancement. However, the extent of orthodontically induced external apical root resorption (OIEARR) differs significantly between the two appliances, with Forsus™ demonstrating a higher predisposition for root resorption. These findings underscore the importance of careful appliance selection based on patient-specific factors**.**

Keywords: *AdvanSync™ 2, Forsus™, Orthodontically induced external apical root resorption.*

1. INTRODUCTION

Skeletal Class II malocclusion is one of the most prevalent jaw discrepancies encountered in orthodontic practice, affecting a significant portion of the population. The prevalence of skeletal Class II malocclusion in North Indian population ranges between 10% - 15% as reported by Kharbanda et al. (1995).1 It usually presents with maxillary prognathism with a normal mandible or mandibular retrusion with a normal maxilla, or a combination of both. Patients with Class II malocclusion often exhibit a convex facial profile, necessitating early

intervention to prevent complex treatments later. If left untreated, corrective measures such as premolar extractions or orthognathic surgery may become necessary. Beyond aesthetics, Class II malocclusion can impact masticatory function, increase the risk of trauma to maxillary incisors, and contribute to temporomandibular joint dysfunction.

Treatment strategies for Class II malocclusion vary depending on the patient's growth stage. Growth modification is most effective during peak puberty, with functional appliances aiding mandibular advancement. These appliances can be removable, like the Twin Block and Bionator, or fixed, like the Herbst appliance, Forsus™or Fatigue Resistant Deviceand AdvanSync™2 appliances.[2-6]Fixed functional appliances (FFAs) are particularly beneficial in post-pubertal patients, offering continuous force for mandibular repositioning with minimal patient compliance.

Among FFAs, Forsus™ or Fatigue Resistant Device marketed by 3M Unitek™ and AdvanSync™2 marketed by Ormco™ have garnered significant attention for their effectiveness in Class II correction.[7]

The effectiveness of functional appliances remains an area of debate, with studies suggesting that skeletal changes are often accompanied by significant dentoalveolar effects. While mandibular advancement occurs, appliances like Forsus™ and AdvanSync™2 may lead to excessive proclination of mandibular incisors, which can compromise long-term stability.[8] Additionally, prolonged use may contribute to orthodontically induced inflammatory root resorption (OIIRR), affecting the integrity of anterior teeth.[9,10] Traditional radiographic methods like cephalograms and periapical radiographs have been used to evaluate these changes, but their limitations necessitate more advanced imaging techniques for accurate assessment.

The present study aimed to determine the amount of orthodontically induced external apical root resorption and change in tooth inclination in skeletal Class II patients with fixed functional appliances AdvanSync™2 and ForsusTM using Cone Beam Computed Tomography.

CBCT provides precise three-dimensional insights into incisor inclination changes and root resorption patterns. By analysing these factors, the study may assist in refinement of treatment protocols, optimizing appliance selection, and contributing to evidence-based orthodontic decision-making. This research will help orthodontists minimize adverse effects while ensuring biologically and mechanically stable Class II corrections, improving long-term treatment outcomes.

MATERIALS AND METHODS

The study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics in collaboration with the Department of Oral Medicine and Radiology at Sardar Patel Post Graduate Institute of Medical and Dental Sciences, Lucknow. A total of 20 patients, with a mean age of 16.6 years, meeting specific inclusion criteria, were enrolled.

The ethical clearance for this study was obtained from the Institutional Ethical Committee (FR/11/IEC/SPPGIDMS/2022). An informed consent was secured from all participants and their parents.

The inclusion criteria required patients with skeletal Class II malocclusion due to a retrusive mandible (ANB >4º), horizontal to normal growth patterns (FMA ≤25), post-pubertal growth stage (CVMI 5 or 6), and Angle's Class II Division 1 malocclusion with an overjet >5 mm. Other conditions included full or half cusp Class II, upright lower incisors (IMPA 89°-100°), minimal mandibular crowding (≤2-3 mm), fully erupted permanent teeth (including second molars), good periodontal status, and no temporomandibular joint disease or syndromic conditions. Exclusion criteria included patients with skeletal Class II due to a prognathic maxilla, those requiring extractions (except third molars), missing mandibular anterior teeth, periodontal bone loss, or local/systemic diseases.

The patients were divided into two groups: Group I received AdvanSync™2 and Group II received Forsus™ FRD, each for a period of 6 to 12 months. The treatment followed a standardized MBT preadjusted appliance protocol with 0.022-inch slots, progressing to 0.019×0.025-inch stainless steel archwires before appliance placement (Figure 1). This archwire was left in both arches for a period of 4 weeks before placement of a fixed functional appliance for correction of skeletal Class II malocclusion due to retrusive or retropositioned mandible.The patients were divided into two groups depending on the type of fixed functional appliance they received.Group I - A total of 10 patients received AdvanSync 2 (Ormco Co, Glendora, California, USA) for a period of 6 to 12 months (Figure 2).roup II - A total of 10 patients received Forsus or FRD (3M Unitek Corp, Monrovia, California, USA) for a total duration of 6 to 12 months (Figure 3). The transpalatal arch was placed in the maxilla, second molar-to-second molar figure of 8 with stainless steel ligature wire and cinch-back of 0.019X0.025-inch stainless steel archwire was done prior to placement of Forsus (with L-pin) to enable anchorage reinforcement. The mandibular push rod was placed on the tear drop loop that was placed distal to canine to avoid direct stress over the mandibular cuspid bracket which may eventually cause breakage. A "v" bend was placed distal to lower lateral incisor on either side to place labial root torque in the incisal area.

The fixed functional appliances were activated by placing split crimps for sagittal advancement of the lower jaw till an overcorrected edge-to-edge incisor relationship was achieved. Cone - beam computed tomography (CBCT) images (i-CAT CBCT scanning 2.0) machine (Figure 4); with a field of view 110 cm, 120 kVp, 5 mA tube current and isometric voxels of 0.25 X 0.14 µ, scanning time of 4 seconds) of the mandibular anterior region were made with patients seated in an upright position, eye-ear plane parallel to the floor and teeth in maximum intercuspation.CBCT scans (Figure 4, 5) were taken at two

time points: T_0 (before appliance placement) and T_1 (immediately after removal, 6 to 12 months later). The primary parameters analysed included apical root resorption, measured using the axial-guided navigation (AGN) method (Figure 6), and tooth inclination (Figure 7), determined by the angle between the long axis of the tooth and the horizontal symphyseal baseline. A total of 40 scans (pre- and post-treatment for each group) were analysed, without an untreated control group to avoid unnecessary radiation exposure. CBCT data were exported in DICOM format and processed using In-vivo imaging software (Version 5.3; Figure 5). Measurements were conducted by a single observer, recorded in an Excel sheet, and subjected to statistical analysis.

STATISTICAL ANALYSIS

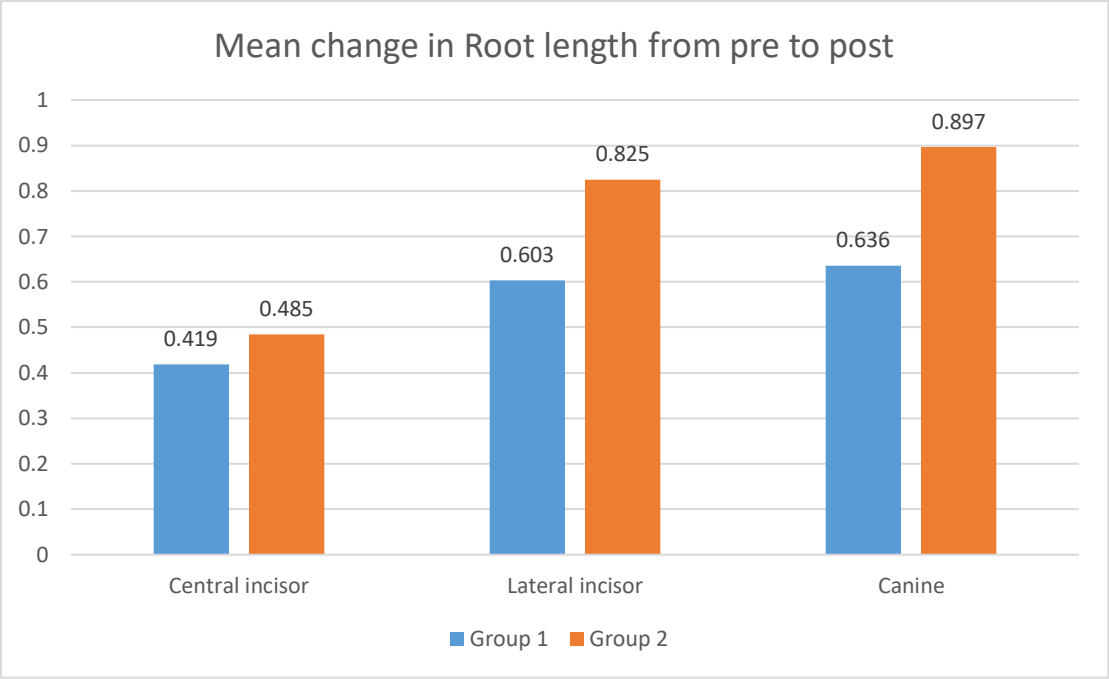
Measurements were reassessed randomly after a two-week interval by the same examiner to ensure reliability. The intraclass correlation coefficient (ICC) demonstrated good-to-excellent reliability, confirming the reproducibility of the method used in the study (Table 2).Data analysis was performed using SPSS version 21. Since all variables were measured on a ratio scale, they were summarized as means and standard deviations. The Shapiro-Wilk test was used to assess data distribution, which was found to be non-normal.Due to the non-normal distribution, inferential statistics were calculated using non-parametric tests, including the Wilcoxon signed-rank test and the Mann-Whitney U test. The significance level was set at 0.05, and graphical representations were prepared using Microsoft Excel.

RESULTS

The mean changes in mandibular anterior teeth between T_0 and T_1 for Groups I and II are summarized in Table 3, while Table 4 presents a comparative analysis of the mean differences between both groups.

ROOT RESORPTION

The maximum mean reduction in root length was observed in the mandibular canines (33), followed by the mandibular lateral incisors (32), and least in the mandibular central incisors (31) in both groups. However, the reduction in root length was more significant in patients treated with Forsus™ FRD (Group II) compared to those treated with AdvanSync™2 (Group I).



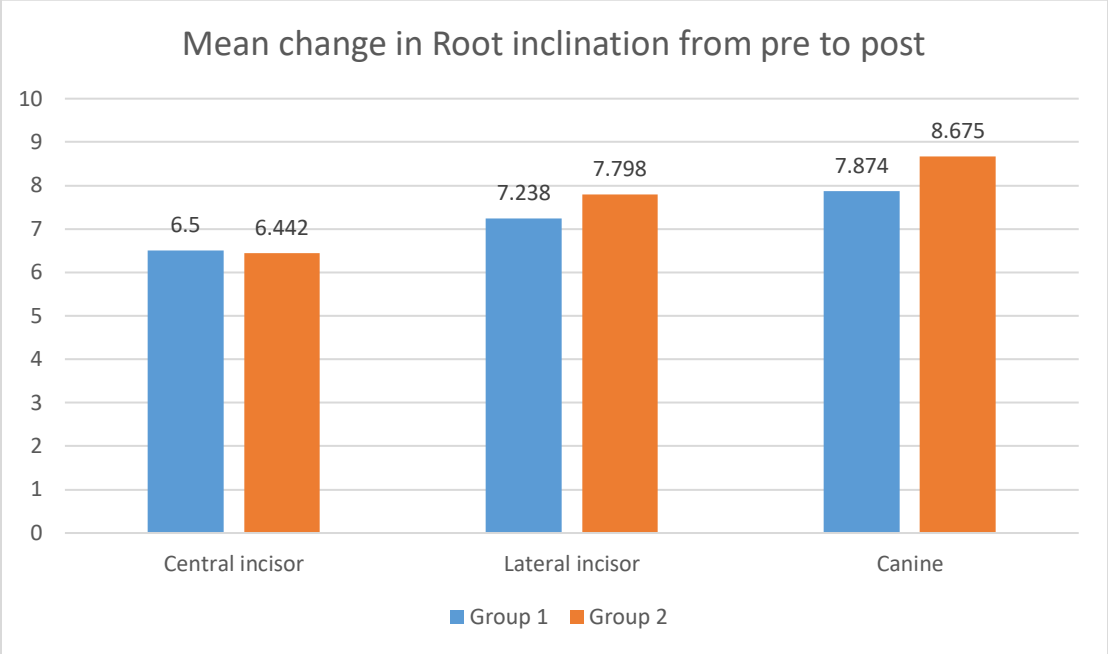
Graph 1: Mean change in root length between Group 1 and Group II

The difference in root length reduction between the two groups was statistically significant for the mandibular lateral incisor ($p<0.005$) and highly significant for the mandibular canines ($p<0.001$) (Table 4, Graph 1).

ROOT INCLINATION

The maximum mean change in root inclination was also noted in the mandibular canines (33), followed by the mandibular lateral incisors (32), and least in the mandibular central incisors (31) in both groups. The increase in root inclination was higher in patients treated with Forsus™ FRD (Group II) compared to those treated with AdvanSync™2 (Group I).

The increase in root inclination was statistically significant for both the mandibular lateral incisors and mandibular canines ($p<0.001$) (Table 4, Graph 2).



Graph 2: Mean change in root inclination between Group 1 and Group II

The Wilcoxon signed-rank test was used to compare changes between T0 and T1 within each group (Table 3), while the Mann–Whitney U test was used to compare post-treatment changes between Group I and Group II (Table 4).

Reduction in root length was statistically significant ($p<0.005$) for mandibular lateral incisors and highly significant ($p<0.001$) for mandibular canines.

Increase in root inclination was statistically highly significant ($p<0.001$) for mandibular lateral incisors and canines between the two groups.

These findings suggest that Forsus™ FRD (Group II) caused greater root resorption and changes in root inclination compared to AdvanSync™2 (Group I), indicating a higher level of orthodontic forces and biomechanical effects associated with Forsus™ FRD therapy.

Table 1 shows the baseline data of the patients included in the study.

Table 1. Baseline data of study subjects before Placement of Fixed Functional Appliance						
	Mean	Standard Deviation	Minimum	Maximum	95% CI	
					Lower	Upper
ANB	4.81	1.55	2.5	8.0	3.99	5.64
FMA	26.09	4.54	17.0	34.0	23.68	28.52
IMPA	98.59	6.15	89.0	111.0	95.32	101.87

Table 2: Intraclass correlation statistics to assess the reproducibility of measurements between 2 weeks for different study parameters

Intraclass correlation coefficient (ICC)			
Parameter	Tooth	ICC	P value
Root length	31	1.00	<0.001, S

	32	1.00	<0.001, S
	33	1.00	<0.001, S
Root inclination	31	1.00	<0.001, S
	32	1.00	<0.001, S
	33	1.00	<0.001, S

Table 3: Mean changes in mandibular anterior teeth between T0 and T1 in group I and II using Wilcoxon signed-rank test

Parameters	Group 1 (Patients treated with AdvanSync™2)				Group 2 (Patients treated with FORSUS™)				P value	
	T0		T1		T0		T1		Group 1	Group 2
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Root length										
31	10.8150	.19727	10.3960	.16249	16.2930	.60775	15.8080	.61642	0.004, S	0.005, S
32	11.8400	.14360	11.2370	.14392	12.7590	.18333	11.9340	1.23725	0.005, S	0.004, S
33	15.7400	.30441	15.1040	.32028	11.3340	.18228	10.4370	1.68758	0.004, S	0.005, S
Root inclination										
31	67.4700	.85121	60.9700	1.08837	69.2030	.51067	62.7610	.52956	0.005, S	0.004, S
32	66.2100	.34798	58.9720	.30433	66.9070	.44229	59.1090	.48135	0.005, S	0.005, S
33	72.1740	.44370	64.3000	.35712	72.7050	.47219	64.0300	.38827	0.005, S	0.005, S

Table 4: Comparison of mean difference (post and pre-Rx) of changes in mandibular anterior teeth between groups I and II using Mann–Whitney U test

Parameters	Group 1 (Patients treated with AdvanSync™2)		Group 2 (Patients treated with FORSUS™)		Mean difference	P value
	Mean	SD	Mean	SD		
Root length						
31	.4190	.04483	. 4850	.02593	0.478	0.814, NS
32	.6030	.02163	.8250	1.13357	0.222	0.002, S
33	.6360	.03239	. 8970	1.56464	-0.151	<0.001, S
Root inclination						
31	6.5000	.34960	6.4420	.10528	.05800	0.444, NS
32	7.2380	.24197	7.7980	.11351	-3.56000	<0.001, S
33	7.8740	.30931	8.6750	.13762	-.80100	<0.001, S

Figure 1: MBT preadjusted appliance (3M Unitek Orthodontic Products, Monrovia, Calif) with 0.022-inch slots with 0.019X0.025-inch stainless steel archwires

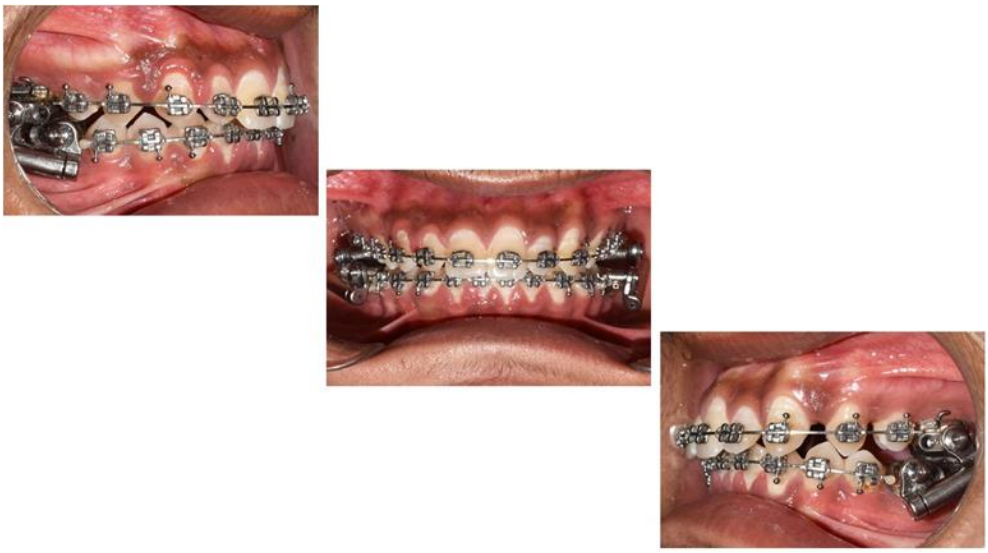


Figure 2: AdvanSync 2 (Ormco Co, Glendora, California, USA)

Figure 3: Forsus FRD (3M Unitek Corp, Monrovia, California, USA)

Figure 4: i-CAT CBCT scanning 2.0

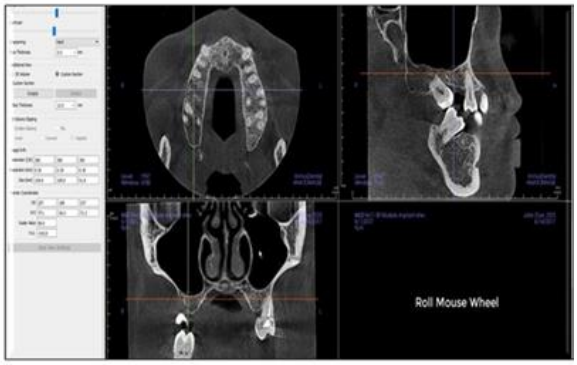


Figure 5: In-vivo imaging software version 5.3

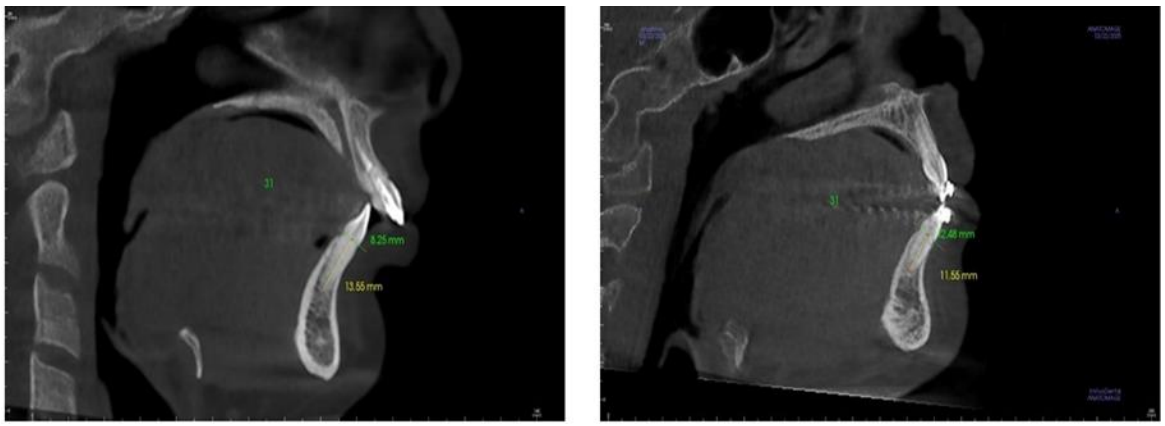


Figure 6: Axial-guided navigation (AGN) method for measuring root length of mandibular anteriors at T0 - before the start of the fixed functional appliance and T1 - 6 to 12 months immediately after the removal of the fixed functional appliance.

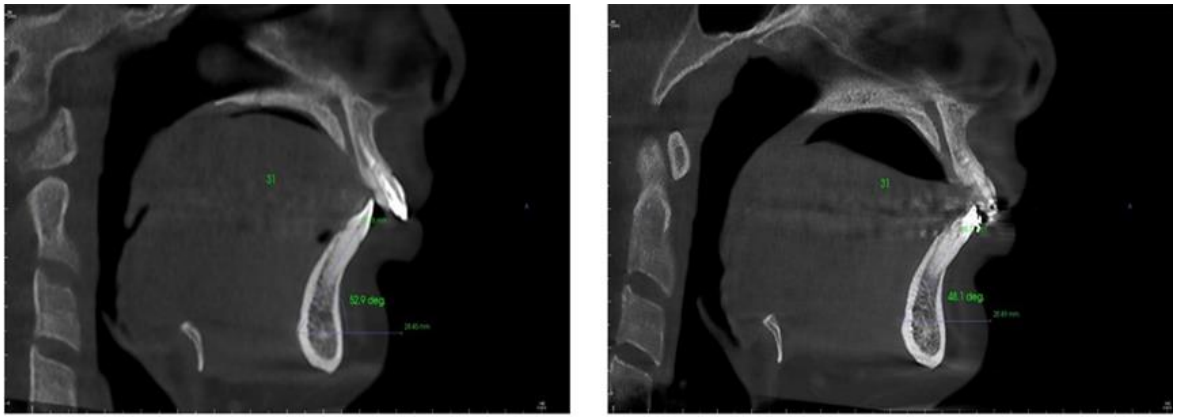


Figure 7: Measurement of tooth inclination of mandibular anteriors at T0 - before the start of the fixed functional appliance and T1 - 6 to 12 months immediately after the removal of the fixed functional appliance.

DISCUSSION

Skeletal Class II malocclusion, characterized by mandibular retrognathia, maxillary prognathism, or both, is a common orthodontic concern. Its correction is essential for both functional efficiency and facial aesthetics, with treatment effectiveness largely dependent on the patient's growth status. Growth modification strategies, including functional appliances, are most effective in growing individuals.

Functional appliances, both removable and fixed, facilitate mandibular advancement during the pubertal growth phase. Fixed Functional Appliances (FFAs), such as Forsus™ (Fatigue Resistant Device) and AdvanSync™2, are beneficial in post-pubertal patients as they do not rely on compliance. These appliances achieve Class II correction by repositioning the mandible anteriorly and producing skeletal and dentoalveolar changes. Over time, advancements in Fixed Functional Appliances have led to improved treatment efficacy while minimizing adverse effects.

Several studies have assessed the skeletal and dentoalveolar effects of FFAs. Franchi et al.[9] and Guintini et al.[10]suggested that FFAs achieve correction through a combination of maxillary growth restriction and mandibular advancement. While Al-Jewair et al.[11] and Cacciatore et al.[12] reported that the primary mechanism is dentoalveolar compensation, with significant mesial movement and proclination of mandibular incisors.

Earlier research relied on two-dimensional imaging which had limitations in assessing three-dimensional changes.[13]Bercoet al.[14] concluded that CBCT provides a superior evaluation of craniofacial structural changes compared to conventional two-dimensional imaging, offering greater accuracy in assessing bone and root modifications.

ROOT RESORPTION

The present study found that root resorption was most pronounced in mandibular canines, followed by lateral incisors, with the least effect on central incisors in both groups.(Group I or subjects treated with Advansync 2; 31- 0.4190; 32- 0.6030 and 33- 0.6360 / Group II or subjects treated with Forsus; 31- 0.4850; 32- 0.8250 and 33- 0.8970) However, root resorption was greater in Forsus™-treated patients compared to those treated with AdvanSync™2. This difference was statistically significant for mandibular lateral incisors ($p<0.005$) and highly significant for mandibular canines ($p<0.001$). The greater resorption in canines is attributed to the positioning of the Forsus™ push rods distal to the cuspids, imparting maximum force. AdvanSync™2, although a molar-to-molar appliance, still exerts progressive mesial-directed forces, impacting the canines the most.

These findings align with previous studies Pavlinet al.[15] and Han et al.[16] which reported significant root resorption with FFAs, particularly Forsus™, due to increased periodontal ligament stress. Coban et al.[17]and Narendran et al. [18] further supported these findings, highlighting the role of continuous intrusive forces by Fixed Functional appliances in exacerbating external apical root resorption.

TOOTH INCLINATION

The study also revealed a significant increase in tooth inclination in both the groups, with Forsus™-treated patients exhibiting greater mandibular anterior proclination than AdvanSync™2-treated patients ($p<0.001$). Canines showed the most inclination change, followed by lateral and central incisors.

This aligns with findings by Linjawi et al.19,Roopa et al.20 and Rekhawat et al.21who reported greater labial tipping of mandibular teeth in Forsus™ patients due to its mode of attachment distal to the canines, exerting greater force on the anterior segment. In contrast, AdvanSync™2, being a molar-to-molar appliance, eliminates direct force on the canines, allowing for

simultaneous orthodontic and orthopedic corrections while reducing proclination and root resorption.

These findings suggest that while both appliances are effective in treating skeletal Class II malocclusion with mandibular retrognathia; Forsus™ tends to induce greater changes in root resorption, inclination, and bone remodelling than AdvanSync™2. This highlights the need for careful case selection and monitoring when opting for fixed functional appliances, particularly in patients with compromised periodontal health. Additionally, Bachdak et al. [22]recommended adjunctive use of anchorage reinforcement strategies, such as Temporary Anchorage Devices, to mitigate excessive incisor proclination and root resorption in Forsus™ therapy. Furthermore, research by Acar A et al.[23]explored the benefits of intermittent force application in reducing negative periodontal effects while maintaining treatment efficiency. Zymperdikas et al.[24]reported that fixed functional appliances are effective in improving Class II malocclusion in the short term with mainly dentoalveolar and soft tissue changes rather than skeletal changes.

It is clear from this study that various appliances are available to treat varying degrees of skeletal malocclusion. However, the outcome of treatment depends greatly on proper diagnosis, selection, and management of cases. Newer techniques should be explored to minimize adverse effects. Further studies with a larger sample size, a narrower age group, and higher imaging techniques like micro-CT should be conducted. Additionally, long-term follow-ups should be performed to further justify the effectiveness of fixed functional appliances in treating Class II malocclusion.

CONCLUSION

This study evaluated orthodontically induced external apical root resorption in skeletal Class II patients treated with AdvanSync™2 and Forsus™ using Cone Beam Computed Tomography. Results showed that both appliances caused more root resorption and inclination in mandibular canines and lateral incisors, with Forsus™ leading to significantly greater root length reduction and inclination compared to AdvanSync™2. These findings indicated that while both appliances effectively correct mandibular retrognathia, Forsus™ induced increased root resorption and greater changes in the tooth inclination.

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