

# Comparison of Apical Root Resorption in Patients Treated with Fixed Orthodontic Appliance and Clear Aligners: A Cone-beam Computed Tomography Study

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## ABSTRACT

**Aim and objective:** To carry out comparison of apical root resorption (ARR) in the fixed orthodontic appliance and clear aligners with the help of cone-beam computed tomography (CBCT) imaging.

**Methods and materials:** The study was conducted on 576 roots in 110 patients. These patients were divided into two groups such that each group consisted of 55 patients. A total of 288 roots were analyzed in each group. One group consisted of patients treated with the conventional fixed orthodontic appliance. Another group consisted of patients treated with clear aligners. Radiographic images were collected with the help of CBCT for each patient. One image was collected before treatment while another image was collected after treatment. The length of the root of the anterior tooth was measured with the help of CBCT images. The ARR was calculated for each tooth by obtaining the difference between the length of the root measured before orthodontic treatment and after orthodontic treatment. The data were recorded, and statistical analysis was carried out with the help of the paired *t* test and Chi-square test to compare ARR between the two groups.

**Results:** The ARR was more in patients who were treated with fixed orthodontic treatment than in those patients who were treated with clear aligners. The mean value of ARR in fixed orthodontic appliances was  $1.51 \pm 1.34$  mm, whereas the mean value of ARR in clear aligners was  $1.12 \pm 1.34$  mm. The severity of ARR in the clear aligners group (on average) was significantly less than that in the fixed appliances group (on average). It was found that ARR in each individual's tooth included in the study was more in case of the fixed orthodontic appliance as compared with clear aligners ( $p < 0.001$ ).

**Conclusion:** From the present study, it can be concluded that the amount of resorption at the root apex is less among patients who undergo treatment using clear aligners as compared with those treated with conventional fixed orthodontics appliances.

**Clinical significance:** ARR found in the orthodontic treatment is a process that causes loss of hard dental tissues such as dentine and cementum at the root apex. Fixed orthodontic appliances are most common method of orthodontic treatment. However, clear aligners are also used commonly for orthodontic treatment.

**Keywords:** Apical root resorption, Clear aligners, Cone-beam computed tomography, Fixed orthodontic appliances.

*The Journal of Contemporary Dental Practice* (2021): 10.5005/jp-journals-10024-3119

## INTRODUCTION

Apical root resorption (ARR) is a common negative outcome of orthodontic treatment which involves removal of hard dental tissues from the root apex.<sup>1</sup> ARR in orthodontics is due to the formation of the hyalinized areas at the root apex as a result of orthodontic forces being transferred to the teeth during orthodontic treatment. There is induction of inflammatory reaction at the root apex, leading to the removal of hard dental tissues such as cementum from the root apex causing root resorption. It is a both physiological as well as pathological process in the periodontal area at the root apex as a result of inflammatory reaction.<sup>2</sup> It has been found that multinucleated giant cells, namely dentinoclasts, have been involved actively in the process of root resorption. ARR in orthodontic treatment is a multifactorial phenomenon. It is affected by several factors of orthodontic treatment such as type of the orthodontic appliance used, type of technique used, amount of force applied, direction of application of force, type of force used, sequence of wire, duration of treatment, and amount of apical movement.<sup>3</sup> ARR has several disadvantages such as loss of the tooth structure at the root apex which can cause change in the ratio between the length of the root and length of the crown of the teeth. Besides, there can be loss of the tooth in severe condition.<sup>4</sup>

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**How to cite this article:** Jyotirmay, Singh SK, Kumar A, *et al.* Comparison of Apical Root Resorption in Patients Treated with Fixed Orthodontic Appliance and Clear Aligners: A Cone-beam Computed Tomography Study. *J Contemp Dent Pract* 2021;22(7):763–768.

**Source of support:** Nil

**Conflict of interest:** None

Fixed orthodontic treatment is the most common technique of orthodontic treatment. There are several disadvantages of this technique such as patient discomfort, poor esthetics, and marked apical root resorption. In order to decrease the patient discomfort

and improve the esthetic value, a new clear aligner therapy (CAT) has been introduced.<sup>5</sup> CAT is the term used for various orthodontic appliances using aligners made of thermoformed plastic. It includes different types of orthodontic appliances which have different methods of action and different methods of fabrication as well as ability to treat different malocclusions. Therefore, they can be used for management of a wide range of orthodontic problems with least patient discomfort and good esthetics. Computer aided design and computer aided manufacturing (CAD/CAM) can be used to provide more esthetic appliances to the patients. With the help of this technology, polymer-based clear aligners can be provided to the patients who require more comfortable and esthetic appliances. Studies should be conducted to evaluate resorption at the root apex due to the use of these appliances.<sup>6,7</sup>

The most common diagnostic methods being used for ARR include two-dimensional radiographs such as panoramic radiographs and intraoral radiographs.<sup>8</sup> But the severity of ARR cannot be accurately analyzed from two-dimensional radiographs because ARR is a three-dimensional phenomenon.<sup>9</sup> With the availability of the three-dimensional imaging technique such as cone-beam computed tomography (CBCT), the process of measuring ARR has been more accurate and reliable. CBCT provides precise details about the measurements and the geometry of changes in the tooth structure during ARR.<sup>10</sup> Besides, CBCT provides the standardized method for comparing two different groups of orthodontic appliances for ARR.

Although clear aligners are more comfortable for patients than the conventional fixed orthodontic appliances, there is still a need to compare ARR in these two appliances because very few studies have been conducted to assess ARR in clear aligners.<sup>11,12</sup> Hence, this study was conducted to compare the amount of resorption at the root apex in patients who underwent treatment using clear aligners and those patients who underwent treatment using fixed orthodontic appliances. The analysis was performed with the help of CBCT.

## MATERIALS AND METHODS

The study was conducted on 576 roots in 110 patients in the Department of Orthodontics in Patna Dental College, Patna. Clearance was obtained from the ethical committee. Informed written consent was obtained from each participant. It was a cohort study which was retrospective in nature. The duration of the study was of 30 months extending from October 2017 to March 2020. The cases for treatment of crowding of the teeth, proclination of the teeth, and spacing of the teeth were included in the study. These patients were divided into two groups such that each group consisted of 55 patients. One group consisted of patients treated with conventional fixed orthodontic appliances (3M, USA).

The patients included in this study were those who didn't have the history of previous orthodontic treatment by conventional orthodontic appliances and clear aligners. The other conditions for including patients in this study were presence of the permanent teeth without any missing tooth and no history of major dental treatment. The conditions for excluding the patients from the study were presence of the history of trauma of face and presence of oral problems such as caries, periodontal disease, and severe root resorption in the anterior teeth. A previous history of endodontic treatment and orthodontic treatment in the anterior teeth and presence of syndromes of craniofacial deformities and skeletal defects, such as cleft lip and palate, also leads to the exclusion of the patients from the study. Those patients with TMJ disorders and supernumerary teeth were also excluded from the study.

**Table 1:** Comparison of the discrepancy index between the two groups

	Fixed appliances	Clear appliances	p value
IMPA angle	5.14 ± 4.87	4.21 ± 3.76	0.433
Overbite	0.57 ± 0.78	1.12 ± 1.38	0.034
SN-MP angle	1.23 ± 1.87	2.12 ± 2.32	0.009
Anterior open bite	0.27 ± 1.32	0.67 ± 2.34	0.201
ANB angle	2.35 ± 2.36	2.19 ± 2.43	0.881
Lateral open bite	1.76 ± 2.21	0.08 ± 0.56	0.004
Posterior cross bite	0.24 ± 0.09	0.71 ± 0.87	0.076
Crowding	1.712 ± 2.27	2.34 ± 2.12	0.045
Overjet	2.87 ± 1.15	3.43 ± 3.67	0.312
Occlusion	1.87 ± 2.89	2.34 ± 2.54	0.123
Total score	16.13 ± 11.23	17.10 ± 12.34	0.561

In order to compare the difficulty level in both the groups of patients, the discrepancy index (DI) was used as prescribed by the American Board of Orthodontics.<sup>17</sup> Several characteristics were taken as the baseline characteristics, and the overall DI score was calculated for each group (Table 1). It was found that the DI score in the clear aligners group was 17.10 ± 12.34, whereas in the conventional fixed orthodontic treatment group, the average DI score was 16.13 ± 11.23. The difference in the DI score was not statistically significant ( $p \leq 0.05$ ). It showed that the level of difficulty in the two groups was similar (Table 1).

CBCT scan images were taken for all the patients included in the study both before the treatment and after the treatment with conventional fixed orthodontic appliances and clear aligners (Figs 1A, 1B and 2A, 2B). The same CBCT machine (Vatech 3D, Korea) was used for conducting all the CBCT scan. The settings were adjusted as per the manufacturer instructions. The field of view was adjusted at 10 × 10 cm, Kilovoltage (KV) was adjusted at 85; milliamperage (mA) was adjusted at 4; and rotation was adjusted at 360°. It was taken care that while obtaining CBCT scan image, patients were in sitting position and were static in position so that their Frankfort plane was parallel with the ground. The assessment for ARR was carried out by measuring the length of the root both before and after the treatment. Then ARR was calculated by comparing the length of the root measured before the start of the treatment and the length of the root measured at the end of the treatment. The root length was measured from the midpoint of the incisal edge up to the root apex with the help of the Blue Sky Plan software program (Blue Sky Bio, USA). For evaluation of ARR, two CBCT investigators who were completely unaware of the study design were selected. They selected CBCT images randomly and measured the ARR without knowing about the other investigator. There was no difference between the calculation made by these two different investigators.

Data were collected, and statistical analysis was carried out. The Student *t* test was used to compare the DI score between the two groups. The statistical analysis for comparing the root resorption at the root apex was carried out with the help of the paired *t* test and Chi-square test.

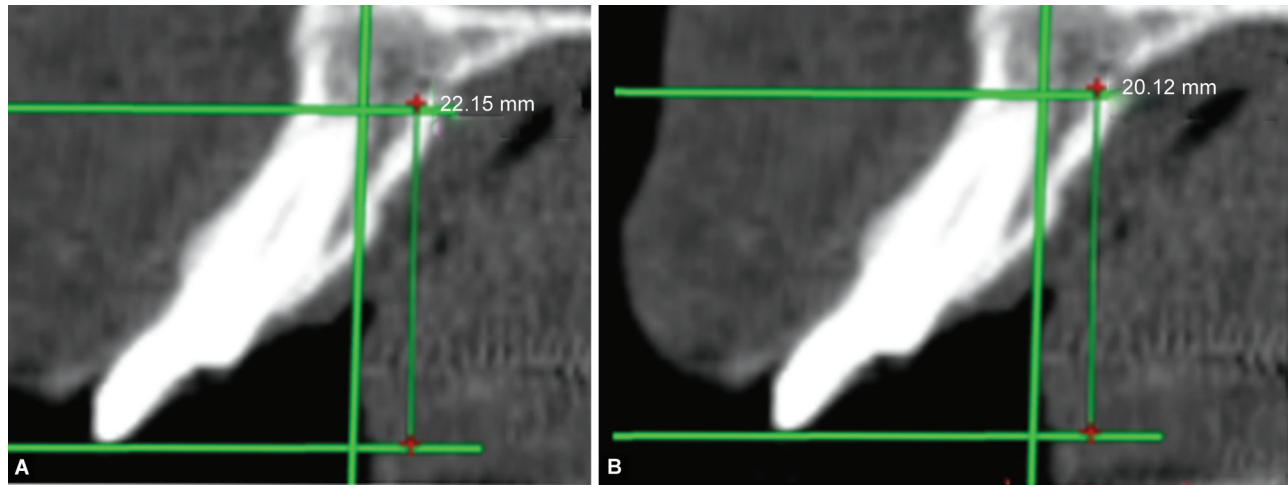
The Sharpe's method was used to assess the severity of ARR in the following manner:<sup>13</sup>

Zero degree = When ARR is 0 mm; No ARR

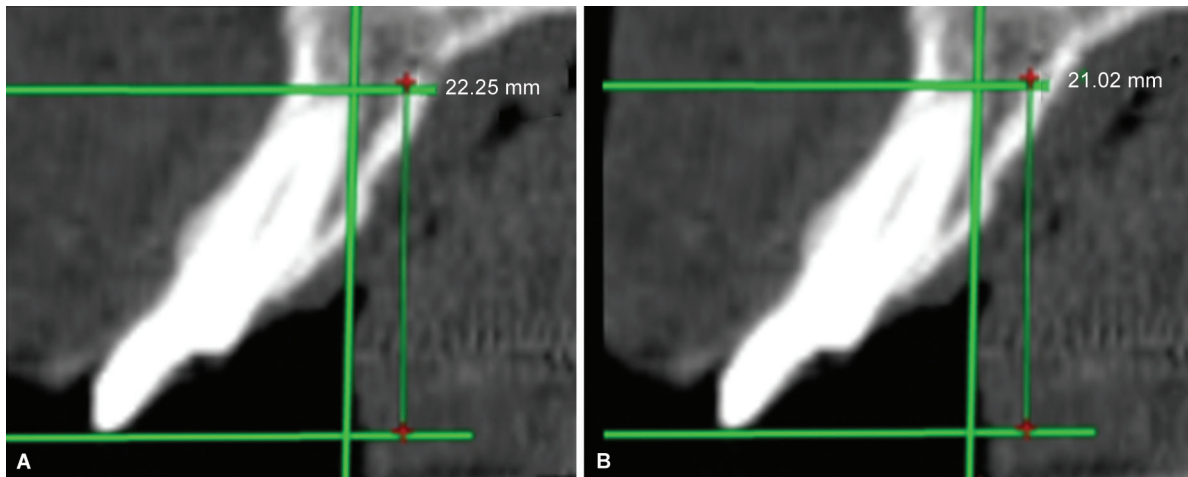
One degree = When ARR is 1–2 mm; Slight ARR

Two degree = When ARR is 2 mm to one fourth of length of root; Moderate ARR

Three degree = When ARR is more than one fourth of the length of the root; Excessive ARR.



**Figs 1A and B:** (A) CBCT scan image before treatment with fixed orthodontic appliance; (B) CBCT scan image after treatment with fixed orthodontic appliance



**Figs 2A and B:** (A) CBCT scan image before treatment with clear aligners; (B) CBCT scan image after treatment with clear aligners

## RESULTS

The mean age of patients in this group was  $23.71 \pm 6.37$  years. Out of 55 patients, 23 were males and 32 were females. The duration of the treatment in this group was  $22.45 \pm 6.54$  months. Another group consisted of patients treated with clear aligners (Inline Aligners, Mumbai). The mean age of the patients was  $21.62 \pm 3.58$  years, and it consisted of 21 males and 34 females. The duration of the treatment in this group was  $22.23 \pm 7.34$  months (Table 2).

The ARR was more in patients who were treated with fixed orthodontic appliances than in those patients who were treated with clear aligners. The mean value of ARR in the fixed orthodontic appliances group was  $1.51 \pm 1.34$  mm, whereas the mean value of ARR in the clear aligners group was  $1.12 \pm 1.34$  mm. When the tooth was considered individually, the ARR was more in case of the fixed orthodontic appliance as compared with clear aligners ( $p < 0.001$ ) (Table 3). In the patients who underwent treatment with fixed orthodontic appliance, there was reduction in the length of the root in all the teeth when comparison was carried out before the start of the treatment and that after the end of the treatment ( $p \leq 0.05$ ).

**Table 2:** Patient details in the two groups of fixed appliances and clear aligners

	Fixed appliances	Clear aligners
Number of cases (n)	55	55
Mean age $\pm$ SD (years)	$23.71 \pm 6.37$	$21.62 \pm 3.58$
Gender		
Males (n, %)	23 (41)	21 (38)
Females (n, %)	32 (59)	34 (62)
Treatment duration $\pm$ SD (months)	$22.45 \pm 6.54$	$22.23 \pm 7.34$
Cases with extractions (n, %)	26 (47)	31 (56)

When the analysis was performed in clear aligners, it was observed that there was reduction in the length of the root in the central incisor of the mandible ( $p \leq 0.05$ ) and the incisors of the maxilla ( $p \leq 0.05$ ). The amount of root resorption at the root apex in patients treated with fixed orthodontic appliances was maximum in the central incisor of the maxilla ( $2.03 \pm 1.31$  mm). The least ARR was reported in the mandibular central incisor ( $0.65 \pm 0.89$ ). The amount of root resorption at the root apex in patients treated with clear aligners was

**Table 3:** Comparison of resorption at the root apex in the individual tooth between the two groups

	<i>Length of root (mean ± SD, mm)</i>		<i>Apical root resorption (mean ± SD, mm)</i>	<i>p value</i>	
	<i>Before treatment</i>	<i>After treatment</i>			
Fixed appliance	1. Central incisor of maxilla	22.15 ± 1.72	20.12 ± 1.94	2.03 ± 1.31	<0.001
	2. Lateral incisor of maxilla	21.32 ± 1.53	19.92 ± 1.86	1.40 ± 1.33	<0.001
	3. Canine of maxilla	23.49 ± 2.19	21.78 ± 2.54	1.71 ± 1.92	<0.001
	4. Central incisor of mandible	17.16 ± 0.99	16.51 ± 1.26	0.65 ± 0.89	<0.001
	5. Lateral incisor of mandible	18.32 ± 0.88	17.40 ± 1.27	1.02 ± 0.98	<0.001
	6. Canine of mandible	21.98 ± 1.71	20.96 ± 2.01	1.02 ± 1.33	<0.001
	Total Average	21.63 ± 1.88	20.42 ± 2.36	1.51 ± 1.34	<0.001
Clear aligners	1. Central incisor of maxilla	22.25 ± 1.85	21.02 ± 1.94	1.23 ± 1.31	<0.001
	2. Lateral incisor of maxilla	20.23 ± 1.53	18.92 ± 1.97	1.31 ± 1.33	<0.001
	3. Canine of maxilla	23.39 ± 2.19	21.86 ± 2.54	1.53 ± 1.92	0.012
	4. Central incisor of mandible	18.26 ± 1.06	17.61 ± 1.26	0.55 ± 0.79	0.032
	5. Lateral incisor of mandible	19.52 ± 1.21	18.50 ± 1.27	1.12 ± 0.87	0.053
	6. Canine of mandible	21.98 ± 1.71	20.96 ± 2.01	1.21 ± 1.22	0.041
	Total Average	20.74 ± 2.31	19.62 ± 2.36	1.12 ± 1.34	0.002

**Table 4:** Overall comparison of the severity of resorption at the root apex between the two groups

<i>Degree of severity</i>	<i>Fixed appliance</i>		<i>Clear aligners</i>	
	<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>
Zero	112	19.45	260	45.13
One	359	62.32	316	54.86
Two	102	17.70	00	00
Three	03	0.005	00	00

maximum in the canine of maxilla (1.53 ± 1.92 mm). The least ARR was reported in the mandibular central incisors (0.55 ± 0.79 mm).

It was observed that the percentage of the teeth in the fixed orthodontic appliance group in which zero degree of ARR was 19.45%. The percentage was 62.32% for the teeth in which one degree of ARR was observed. The percentage was 17.70% for the teeth in which two degree of ARR was observed, and it was 0.005% for the teeth in which three degree of ARR was observed. When analysis was performed in the group of patients who underwent treatment using clear aligners, 45.13% of the teeth showed zero degree resorption of the teeth at the root apex. A total of 54.86% of the teeth showed one degree. It was found that the amount of root resorption at the root apex is more in patients who underwent treatment using fixed orthodontic appliances as compared with the patients who underwent treatment using clear aligners (Table 4).

## DISCUSSION

In the present study, it was found that ARR was significantly less in patients treated with clear aligners as compared with the those

treated with conventional orthodontic appliances. The results are similar to those of the study conducted by Li et al. and Wang et al. which concluded that the amount of resorption at the root apex is lower in patients who underwent orthodontic treatment using clear aligners in comparison with those who underwent treatment using fixed orthodontic appliances.<sup>14,15</sup> A systematic review was conducted by Gay et al. which included three studies, and it was concluded that ARR is also reported in the clear aligners group, but the severity and prevalence is lower as compared with that in the conventional fixed orthodontic appliances group.<sup>16,17</sup> Another study was conducted by Zheng et al. which concluded that when light orthodontic forces are applied, the severity of ARR is similar in the clear aligners group as compared with that in the fixed orthodontic appliances group. The study conducted by Gay et al. also concluded that ARR was observed in 41.81% of the teeth. The ARR was reported mostly in the maxillary and mandibular incisors. This can be explained on the basis of the structure of the root in the incisors and the maximum tooth movement observed in the incisors.<sup>18,19</sup> In the present study also, the maximum amount of ARR was found in the maxillary and mandibular incisors. Almeida et al. also conducted a study using CBCT and found that ARR in the maxillary incisor was 0.59 mm in the fixed orthodontic appliances group. The duration of this study was 8 months. But in our study, the ARR was more, measuring 1.51 mm on average, in the fixed orthodontic appliance group. This can be attributed to the longer duration of the treatment in our study which was of 30 months.

ARR is explained both physiologically and pathologically which mainly causes the removal of hard dental tissues from the root apex of the root such as cementum and dentine.<sup>20,21</sup> Apical resorption of root is very common in fixed orthodontic treatment.





The main reason for this resorption is the inflammation produced in the periodontal ligament at the root apex due to the orthodontic forces. There is a formation of hyalinized zones at the root apex which later get removed along with hard dental tissues such as cementum and dentin at the root apex, causing permanent loss of the tooth structure. It can cause loss of the tooth in severe conditions, causing failure of the treatment and affecting the quality of life of the patients.<sup>22,23</sup>

Conventional fixed orthodontic treatment is the most common technique for orthodontic treatment. However, there are some very regular complaints of this treatment observed such as patient discomfort and poor esthetics. Therefore, patients want alternative treatment techniques which can provide comfort and good esthetics.<sup>24</sup> In recent times, a new orthodontic treatment modality named clear aligners has been introduced with features such as patient comfort, good esthetics, ease in maintaining oral hygiene, reduced pain while wearing orthodontic appliances. Besides, the duration and number of appointments get reduced in using these appliances. Because very few studies have been conducted to assess the severity of ARR in clear aligners, this study was conducted to compare the ARR in the conventional fixed orthodontic appliances group and the clear aligners group. As ARR is a three-dimensional phenomenon, three-dimensional imaging CBCT was used for the analysis of ARR.<sup>25</sup>

In the present study, the difficulty level was compared between the two groups. It was carried out by assessment of the baseline characteristics with the help of the index suggested by the American board of orthodontists (ABO).<sup>26</sup> The patients faced same difficulty in both techniques, and the amount of tooth movement required was same in both the groups, producing same quality of the treatment outcome. In this study, the anterior teeth of the maxilla and mandible were selected because incidence of ARR is more commonly reported in the anterior teeth as compared with the posterior teeth.

The previous studies generally used two-dimensional radiographic techniques such as panoramic radiographs and intraoral periapical radiographs for assessment of ARR.<sup>27</sup> The technique which was used for analyzing root resorption at the root apex in such studies might have influenced the correctness of the analysis of resorption at the root apex. A study was performed by Iglesias et al. to compare the ARR in patients treated with fixed orthodontic appliances and clear aligners. In this study, when the analysis of ARR was performed with the help of panoramic radiographs, the amount of ARR in the maxillary central incisors and lateral incisors was found to be the same. However, when the analysis was performed by using CBCT by Wang et al. in a study, it was found that ARR was greater in those treated with the conventional fixed orthodontic appliances as compared with those treated with clear aligners.<sup>28</sup> The assessment of ARR carried out with the help of panoramic radiography is generally overestimated as compared with that of intraoral periapical radiograph. But as compared with CBCT, the assessment is underestimated in panoramic radiography. It is a well-known fact that changes in resorption of the root at the root apex is demonstrated in three planes. Therefore, two-dimensional radiographic methods which are found to present details in two planes radiographs are unable to give accurate assessment of resorption of the root apex such as Orthopantomograph and IOPAR. On the other hand, CBCT is a three-dimensional imaging technique with the ability of precise measurements of the

morphological and structural changes. It has shown relatively better accuracy in the measurement of ARR.<sup>29</sup>

Kesling in the year 1945 for the first time demonstrated that the movement of the tooth in consecutive manner can be achieved by using positioners devices which also involve development of models in several steps. The model was prepared in accordance with the movement of the tooth using CAD/CAM. All these developments lead to the formation of clear aligners.<sup>30</sup> It has been found that the magnitude of the orthodontic force generated by clear aligners is comparatively higher than that of the conventional fixed orthodontic appliance, but there is a suitable force control as a result of the use of CAD/CAM. Besides, the clear aligners incorporate the treatment process which is intermittent in nature. As a result, the amount of resorption at the root apex is lower in patients who undergo treatment using clear aligners in comparison with patients who undergo treatment using fixed orthodontic appliances.<sup>31</sup>

The limitation of the present study was that patients were subjected to high radiation exposure in CBCT scans twice in the study, one before the treatment and the other after the treatment.

## CONCLUSION

From the present study, it can be concluded that the amount of resorption at the root apex is less in patients who are treated using clear aligners as compared with those treated with conventional fixed orthodontics appliances. However, more studies with a large sample size should be carried out to further support this finding.

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