

Comparison of Anchorage Control in Treatment of Class II Malocclusion with Carriere Motion Appliance using Essix Appliance with Miniscrews – A FEM Study

Muskan Singh^{1*}, Amitabh Kallury², Chetan Jayade¹, Rajesh Kumar Balani¹, Nimisha Chaturvedi¹, Somil Gupta¹

¹Department of Orthodontics and Dentofacial Orthopedics, People's Dental Academy, Bhopal, Madhya Pradesh, India.

²Centre for Orthodontic Research and Education (CORE), Hubli, Karnataka, India.

Abstract

Objectives: The objective of this study was to evaluate anchorage control using mini-screws as compared to an Essix retainer in the treatment of Class II malocclusion to distalize the maxillary molars using the Carriere motion appliance (CMA) with Finite Element Method Analysis. **Materials and Methods:** A cone-beam computed tomography of a patient having Angle's Class II malocclusion was obtained and simulated for making the digital models using Solidworks 2023 software. Boundary conditions and material properties were assigned to the constructed 3D models. **Results:** The mandibular anchorage loss in the treatment of Class II malocclusion with CMA and Essix retainer was more than with mini-screw. **Conclusion:** Overall, the study highlights the effectiveness of the CMA in achieving distalization while minimizing anchorage loss, emphasizing the importance of anchorage control methods in orthodontic treatment planning.

Keywords: Carriere motion appliance, Class II elastics, Correction of Class II malocclusion, Essix retainer, Finite element analysis, Mandibular anchorage loss, Molar distalization, Temporary anchorage device.

INTRODUCTION

Class II malocclusion, characterized by a prognathic maxilla and orthognathic mandible, is a common orthodontic condition requiring precise treatment to achieve favorable occlusal and esthetic outcomes. The correction of Class II malocclusion often involves molar distalization, which, in turn, requires effective anchorage control. Anchorage loss remains a pivotal concern in managing these cases.^[1]

The Carriere motion appliance (CMA), developed by Dr Louis Carriere, represents a versatile and esthetically pleasing approach for Class II correction. It offers a patient-friendly option for achieving molar distalization. Multiple case reports have examined the efficacy of the CMA, and a retrospective study compared treatment outcomes when employing two different types of anchorage in the mandibular arch full fixed orthodontic appliances or a lingual arch and concluded that both methods resulted in proclination of the lower incisors.^[1-3] Other studies investigated the treatment effects of the CMA with the Essix appliance used as anchorage and found significant mesial movement and mesial tipping of the first mandibular molar, alongside proclination of the lower incisors.^[4-6]

Despite these findings, no randomized clinical trial or Finite element study has been conducted to assess anchorage control using miniscrews with the CMA, leaving uncertainty regarding the most effective anchorage method. Therefore, this study focused to compare anchorage control using miniscrews versus an Essix appliance in the treatment of patients with Class II malocclusion using the CMA in conjunction with a class II elastic. On the other hand, temporary anchorage devices (TADs) have gained popularity as temporary skeletal anchorage devices, enabling precise control of tooth movement by providing absolute anchorage. This study aims to address the crucial question of anchorage loss in Class II malocclusion correction by comparing the conventional approach with Essix retainer and Class II elastics versus TAD with Class II elastics.

Address for correspondence: Dr. Muskan Singh,

Department of Orthodontics and Dentofacial Orthopedics, People's Dental Academy, Bhopal, Madhya Pradesh, India.
Email: muskan.singh2212@gmail.com

Received: May. 04, 2024; **Accepted:** May. 11, 2024; **Published:** May. 13, 2024

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

How to cite this article: Singh M, Kallury A, Jayade C, Balani RK, Chaturvedi N, Gupta S. Comparison of Anchorage Control in Treatment of Class II Malocclusion with Carriere Motion Appliance using Essix Appliance with Miniscrews – A FEM Study. J Res Adv Dent 2024;15(4):1-7.

Access this article online

Website:
www.jrad.co.in

DOI:
<https://doi.org/10.53064/jrad.2022.15.4.507>

The null hypothesis states that there would be no disparity in anchorage control between mini-screws and an Essix appliance in the treatment of post-pubertal patients with CMA.^[7-9]

MATERIALS AND METHODS

A cone-beam computed tomography (CBCT) scan of a skeletal Class II malocclusion patient on account of prognathic maxilla and retrognathic mandible was obtained.

Construction of the three-dimensional model

A three-dimensional (3D) finite element model of a representative human maxilla and mandible was created. The model was developed using a CBCT scan. Solidworks 2023 software was used for 3D modeling and meshing.^[10]

Case 1 model specifications

The first case consists of conventional CMA attached from the maxillary canine to the maxillary first molar along with an Essix retainer in the mandibular arch and Class II elastics from the maxillary canine to the mandibular first molar, as shown in Figure 1.^[4]

Case 2 model specifications

The second case Figure 2 consists of CMA attached from the maxillary canine to the maxillary first molar along with a TAD of 1.5×8 mm (S.K. surgicals company) placed mesial to mandibular first molar and Class II elastics continued from the maxillary canine to the TAD.^[4]

Incorporation of dental anatomy

The model included anatomically accurate representations of teeth, periodontal ligaments, alveolar bone, and surrounding soft tissues.

Inclusion of anchorage devices

The CMA was virtually installed from the maxillary canine to the maxillary first molar to simulate molar distalization. A TAD was virtually placed mesial to the mandibular first molar to represent the TAD approach.

Material properties

The material properties of teeth, periodontal ligaments, alveolar bone, and soft tissues were defined based on existing biomechanical data in the literature, as mentioned in Table 1. Specific properties of the CMA and the TAD were obtained from the manufacturer's specifications.^[11]

Boundary conditions

Regarding the boundary conditions, movement of the temporal and maxillary bone was constrained across all degrees of freedom of the nodes at their superior regions as depicted in Figure 3. In addition, the mandible was immobilized at the lower margin. Bonding contact was established for interfaces including spongy-cortical bone, cortical bone-PDL, PDL-tooth, and tooth attachment, preventing any movement between these contact surfaces. Moreover, connections between adjacent teeth were assumed to have no separation from their interfaces, although slight frictionless sliding along the contact surfaces was permitted.^[11]

Application of forces

Distalizing forces of 3.5 ounces (100 g) were applied to the maxillary molars in both Case 1 (CMA with Essix) and Case 2 (CMA with TAD) scenarios, simulating typical clinical conditions.

Finite element analysis

Finite element analysis was performed to calculate and compare stress distributions and displacements under the influence of the Class II elastic forces in Ansys Workbench 19.2. The analysis included evaluations of von Mises stress and displacement vectors to quantify anchorage loss.

Data analysis

Anchorage loss was assessed by measuring the displacement of individual teeth and the mandibular arch as a whole along with the surrounding bone. Ansys Workbench 19.2 software was used for the analysis and interpretation of the results.

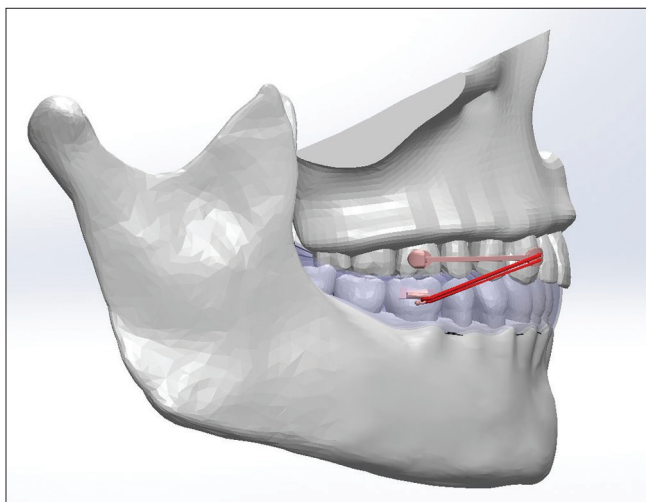


Figure 1: Conventional carriere motion appliance with Essix retainer

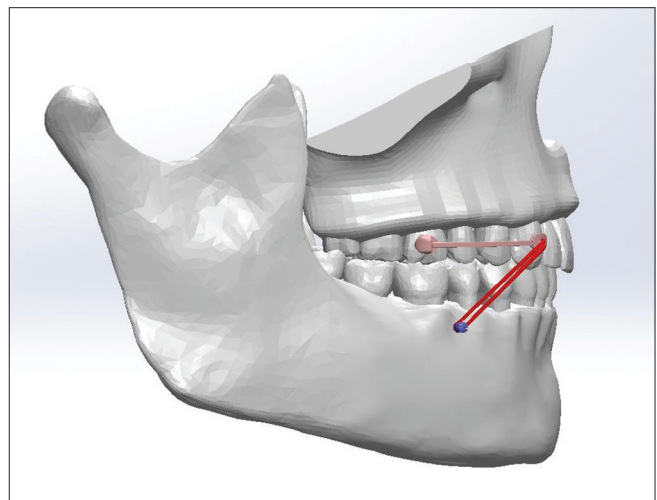


Figure 2: Carriere motion appliance with temporary anchorage device placed mesial to mandibular first molar and Class II elastics

Table 1: Material properties used for FEA analysis

Material	Young's modulus	Poisson's ratio
Tooth	1.96×10^4	0.3
PDL	6.9×10^{-1}	0.45
Cortical bone	1.37×10^4	0.26
Cancellous bone	1.37×10^3	0.30
Essix retainer	5.28×10^2	0.36

FEA: Finite element analysis

Table 2: Table depicting results of average displacement in Case 1 and Case 2

S. no.	Entity	Average displacement in case 1 (mm)	Average displacement in case 2 (mm)
1.	Mandible central incisor	1.01E-05	1.38E-05
	Mandible central incisor X	6.44E-06	1.31E-05
	Mandible central incisor Y	-6.17E-06	-2.30E-06
	Mandible central incisor Z	3.92E-06	1.19E-06
2.	Mandible lateral incisor	9.51E-06	1.42E-05
	Mandible lateral incisor X	6.13E-06	1.37E-05
	Mandible lateral incisor Y	-4.93E-06	1.55E-06
	Mandible lateral incisor Z	5.32E-06	1.04E-06
3.	Mandible canine	8.38E-06	1.54E-05
	Mandible canine X	6.07E-06	1.39E-05
	Mandible canine Y	-3.71E-06	4.59E-06
	Mandible canine Z	4.39E-06	5.37E-07
4.	Mandible first premolar	9.12E-06	1.88E-05
	Mandible first premolar X	6.34E-06	1.58E-05
	Mandible first premolar Y	-3.71E-06	4.23E-06
	Mandible first premolar Z	1.33E-06	-3.06E-06
5.	Mandible 2 nd premolar	9.72E-06	2.31E-05
	Mandible 2 nd premolar X	8.92E-06	1.59E-05
	Mandible 2 nd premolar Y	-9.38E-07	1.33E-05
	Mandible 2 nd premolar Z	3.61E-06	1.68E-06
6.	Mandible first molar	8.15E-06	1.60E-05
	Mandible first molar X	7.05E-06	4.99E-06
	Mandible first molar Y	1.66E-06	1.01E-05
	Mandible first molar Z	3.17E-06	3.87E-06
7.	Mandible second molar	5.73E-06	7.79E-06
	Mandible second molar X	4.85E-06	5.37E-07
	Mandible second molar Y	1.26E-06	3.42E-06
	Mandible second molar Z	2.16E-06	2.29E-06
8.	Mandibular group	9.30E-06	1.45E-05
	Mandibular group X	6.21E-06	1.36E-05
	Mandibular group Y	-4.91E-06	1.35E-06
	Mandibular group Z	4.55E-06	2.13E-07

Outcome assessment

Two coordinate systems were established for reference. The global system was defined for the entire dentition, with the X-axis representing the coronal plane (+ left, -right), the Y-axis indicating the sagittal plane (+ posterior, -anterior), and the Z-axis signifying the vertical plane (+ superior, -inferior). In addition, a local coordination system was defined for each tooth. For this system, the X-axis was denoted (+mesial, -

distal), the Y-axis represented (+lingual, -buccal), and the positive direction on the Z-axis was indicated by the apex of the maxillary teeth, and the incisor/occlusal of the lower teeth. The initial movement of the entire dentition and individual teeth in three directions was recorded.^[12]

RESULTS

The analysis revealed that in Case 2 on the application of approximately 100 g distalizing force from Class II elastics in the maxillary arch, the mandibular arch experienced mesializing force as a result of which there was a mesial movement of the mandibular canine (0.000015371 mm), mandibular lateral incisor (0.000014173 mm), and mandibular central incisor (0.000013762 mm); however, in Case 1, mandibular canine experienced a mesial movement (0.0000083773 mm), mandibular lateral incisor (0.0000095135 mm), and mandibular central incisor (0.000010065 mm) suggesting more anchorage loss in conventional CMA with Essix retainer as compared to CMA with mini-screw group. As displayed in Table 2.

Comparative analysis of the results

Mandibular central incisor

In Case 1, the average displacements are 1.01E-05 mm (X-axis), -6.17E-06 mm (Y-axis), and 3.92E-06 mm (Z-axis).

In Case 2, the average displacements are 1.38E-05 mm (X-axis), -2.30E-06 mm (Y-axis), and 1.19E-06 mm (Z-axis).

The central incisor exhibits increased displacement along all axes in Case 1 compared to Case 2.

Mandibular lateral incisor

In Case 1, the average displacements are 9.51E-06 mm (X-axis), 1.93E-06 mm (Y-axis), and 5.32E-06 mm (Z-axis).

In Case 2, the average displacements are 1.42E-05 mm (X-axis), 1.55E-06 mm (Y-axis), and 1.04E-06 mm (Z-axis).

The lateral incisor exhibits increased displacement along the X and Z axes in Case 1 compared to Case 2, while the displacement along the Y-axis is negligible.

Mandibular canine

In Case 1, the average displacements are 8.38E-06 mm (X-axis), -3.71E-06 mm (Y-axis), and 4.39E-06 mm (Z-axis).

In Case 2, the average displacements are 1.54E-05 mm (X-axis), 4.59E-06 mm (Y-axis), and 5.37E-07 mm (Z-axis).

The canine exhibits increased displacement along all axes in Case 1 compared to Case 2.

Mandibular first premolar

In Case 1, the average displacements are 9.12E-06 mm (X-axis), -3.71E-06 mm (Y-axis), and 1.33E-06 mm (Z-axis).

In Case 2, the average displacements are 1.88E-05 mm (X-axis), 4.23E-06 mm (Y-axis), and -3.06E-06 mm (Z-axis).

The first premolar exhibits increased displacement along all axes in Case 1 compared to Case 2.

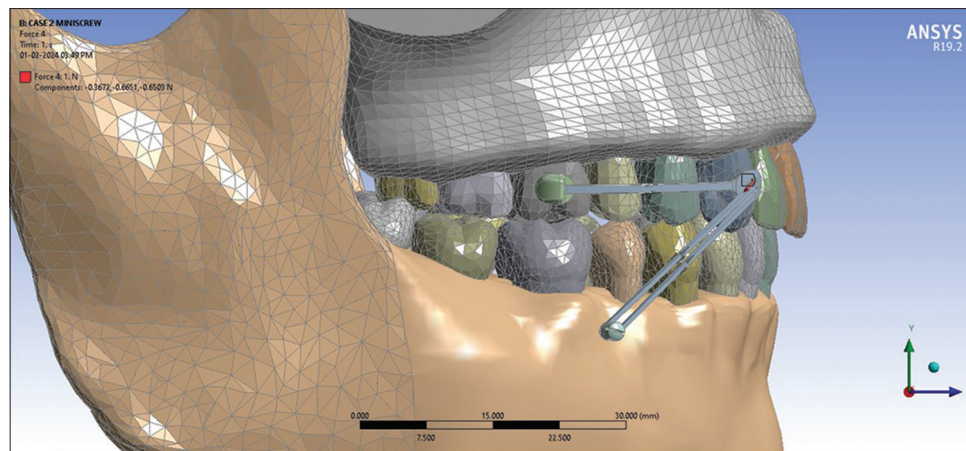


Figure 3: Meshing of the computer-aided design model with boundary conditions included

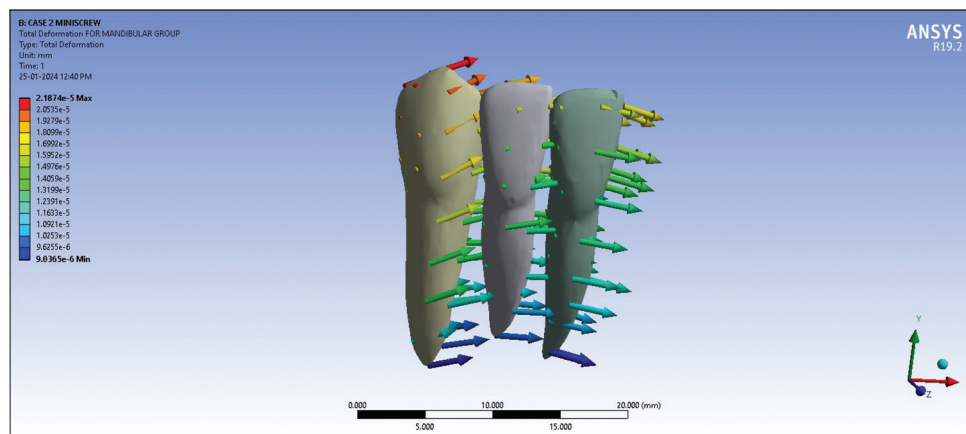


Figure 4: Forces indicating the direction in which the movement will occur

Mandibular second premolar

In Case 1, the average displacements are $3.72\text{E-}06$ mm (X-axis), $-3.38\text{E-}07$ mm (Y-axis), and $3.61\text{E-}06$ mm (Z-axis).

In Case 2, the average displacements are $2.31\text{E-}05$ mm (X-axis), $1.33\text{E-}05$ mm (Y-axis), and $1.68\text{E-}06$ mm (Z-axis).

The second premolar also shows increased displacement along all axes in Case 1 compared to Case 2.

Mandibular first molar

In Case 1, the average displacements are $8.15\text{E-}06$ mm (X-axis), $1.66\text{E-}06$ mm (Y-axis), and $3.17\text{E-}06$ mm (Z-axis).

In Case 2, the average displacements are $6.60\text{E-}05$ mm (X-axis), $1.01\text{E-}05$ mm (Y-axis), and $3.87\text{E-}06$ mm (Z-axis).

The first molar exhibits increased displacement along all axes in Case 1 compared to Case 2.

Mandibular second molar

In Case 1, the average displacements are $5.73\text{E-}06$ mm (X-axis), $1.26\text{E-}06$ mm (Y-axis), and $2.16\text{E-}06$ mm (Z-axis).

In Case 2, the average displacements are $7.79\text{E-}06$ mm (X-axis), $3.42\text{E-}06$ mm (Y-axis), and $2.29\text{E-}06$ mm (Z-axis).

The second molar also demonstrates increased displacement along all axes in Case 1 compared to Case 2 except for Z-axis where it is almost insignificant.

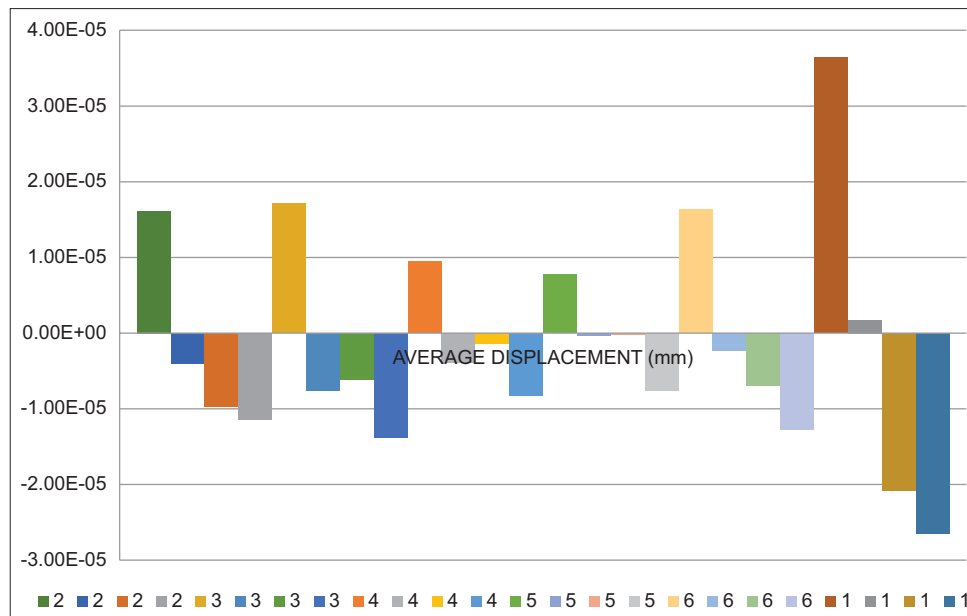
Mandibular group

In Case 1, the average displacements are $9.30\text{E-}06$ mm (X-axis), $-4.91\text{E-}06$ mm (Y-axis), and $4.55\text{E-}06$ mm (Z-axis).

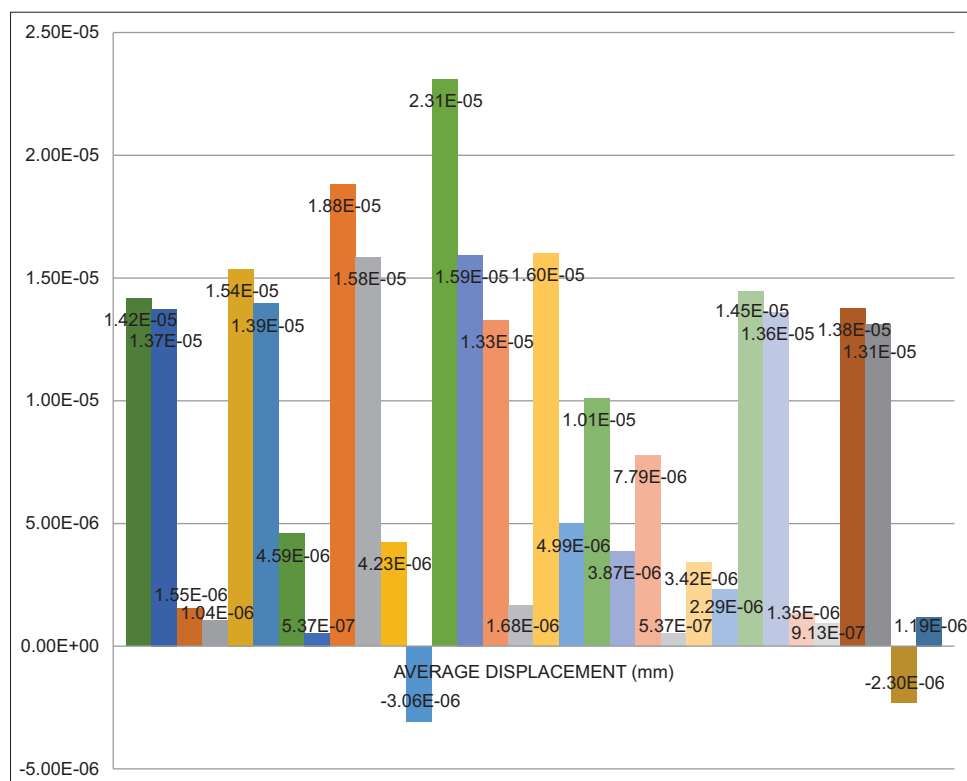
In Case 2, the average displacements are $1.45\text{E-}05$ mm (X-axis), $1.35\text{E-}06$ mm (Y-axis), and $2.13\text{E-}07$ mm (Z-axis).

The mandibular group shows increased displacement along all axes in Case 1 compared to Case 2.

Overall, the observed trend suggests that there is a consistent increase in displacement in case 1 across all evaluated mandibular teeth and the mandibular group as a whole when compared to case 2. This indicates that the treatment conditions or forces applied in case 1 result in greater movement of the mandibular dentition compared to case 2, thus indicating greater amount of anchorage loss in Case 1 as compared to Case 2.



Graph 1: Displaying average displacement of all the teeth in maxillary quadrant in all three planes (X, Y, and Z)



Graph 2: Displaying average displacement of all the teeth in mandibular quadrant in all three planes (X, Y, and Z)

DISCUSSION

The CMA functions by posteriorly displacing the entire maxillary posterior segment, spanning from the maxillary canine to the maxillary first molar, facilitated by the utilization of Class II intermaxillary elastics. This research comprehensively evaluates the extent and manner of distalization achieved by the CMA in a three-dimensional

context. In addition, it aims to scrutinize the repercussions of using Class II intermaxillary elastics in conjunction with two distinct methods of anchorage control within the mandibular arch.^[13]

The null hypothesis made in this trial was proven incorrect, as we found that the extent of forward movement of the incisors was considerably greater in Case 1 in which CMA with the

Essix appliance was compared to the group that relied on mini-screw anchorage.^[14]

There was an observable trend toward greater forward movement and tilting forward of the mandibular second molar in the Essix group (0.0000077905 mm). As depicted in the Graphs 1 and 2. This phenomenon can be attributed to the Essix appliance securing all mandibular teeth together, causing them to function as a singular unit. Consequently, any loss of anchorage was manifested as forward movement and tilting forward of the entire lower arch.^[15] Despite employing a mini-screw to anchor the mandibular second molar, some forward movement and tipping were still evident in Case 2 (0.0000057271 mm). As for the lower incisors, as depicted in Figure 4 lacking any mechanism to unite them as a single unit, it was observed that a few of the incisors were slightly tilted forward.^[16]

The findings of this research focus on the mechanism behind the reciprocal force observed between the maxillary and mandibular arches, which aimed to move the maxillary teeth distally while inducing mesial movement in the mandibular arch.^[17] Altering the anchorage control in the mandibular arch by introducing miniscrews played a pivotal role in tipping the scale towards maxillary distalization. Specifically, the Essix appliance group exhibited greater forward movement in the lower dentition, particularly noticeable in the incisors.^[18]

CONCLUSION

- The impact of distalizing force: Applying distalizing force in the maxillary arch led to the distalization of the maxillary first molar (0.0000084478 mm), second maxillary molar (0.0000077128 mm), and maxillary canine (0.000036387 mm). In Case 2, the maxillary first molar (0.000061058 mm), second maxillary molar (0.0000075176 mm), and maxillary canine (0.000056355 mm) experienced similar distalization effects.
- Anchorage loss: The comparative analysis revealed more anchorage loss in the conventional CMA with Class II elastics (Case 1) than in the CMA with mini-screw anchorage (Case 2).
- Effect on mandibular dentition: There was a noticeable trend of increased displacement in Case 1 across all evaluated mandibular teeth and the mandibular group compared to Case 2, indicating greater movement of the mandibular dentition in Case 1.
- Treatment implications: The findings underscore the importance of considering anchorage control methods in orthodontic treatment planning, as different approaches can significantly affect the outcome of treatment
- Efficacy of CMA: Despite some anchorage loss observed, the CMA demonstrated effectiveness in achieving distalization, particularly when combined with mini-

screw anchorage.

- Clinical significance: Orthodontists should carefully select anchorage control methods based on individual patient needs and treatment objectives to optimize treatment outcomes and minimize unwanted tooth movement.
- Future directions: Further, research could explore alternative anchorage control methods and their impact on orthodontic treatment outcomes to refine treatment protocols and improve patient care.

FUNDING

No funding or grant support.

DECLARATION OF CONFLICTS OF INTEREST

The authors reported no competing financial interests or personal relationships that could appear to influence the work reported in this paper.

ORGANIZATION SUPPORT

We would like to acknowledge the assistance of Engineering DNA, Mumbai, for all FEA Analysis carried out. Institutional Review Board Statement This study is approved under Review Board sequenced - RAC/2023/006/05 and IEC/2023/600/05.

REFERENCES

1. Kim-Berman H, McNamara JA Jr, Lints JP, McMullen C, Franchi L. Treatment effects of the Carriere® Motion 3D™ appliance for the correction of class II malocclusion in adolescents. *Angle Orthod* 2019;89:839-46.
2. Sandifer CL, English JD, Colville CD, Gallerano RL, Akyalcin S. Treatment effects of the Carrière distalizer using lingual arch and full fixed appliances. *J World Fed Orthod* 2014;3:e49-54.
3. Areepong D, Kim KB, Oliver DR, Ueno H. The class II carriere motion appliance: A 3D CBCT evaluation of the effects on the dentition. *Angle Orthod* 2020;90:491-9.
4. Fouda AS, Attia KH, Abouelezz AM, Abd El-Ghafour M, Aboufotouh MH. Anchorage control using miniscrews in comparison to essix appliance in treatment of postpubertal patients with Class II malocclusion using Carrière Motion appliance. *Angle Orthod* 2022;92:45-54.
5. Altug-Atac AT, Erdem D, Arat ZM. Three-dimensional bimetric maxillary distalization arches compared with a modified Begg intraoral distalization system. *Eur J Orthod* 2008;30:73-9.
6. Monga N, Kharbanda OP, Samrit V. Quantitative and qualitative assessment of anchorage loss during en-masse retraction with indirectly loaded miniscrews in patients with bimaxillary protrusion. *Am J Orthod Dentofacial Orthop* 2016;150:274-82.
7. Jang W, Choi YJ, Hwang S, Chung CJ, Kim KH. Anchorage loss assessment of the indirect anchor tooth during adjunctive orthodontic treatment. *Am J Orthod Dentofacial Orthop* 2019;155:347-54.
8. El-Beialy AR, Abou-El-Ezz AM, Attia KH, El-Bialy AM, Mostafa YA. Loss of anchorage of miniscrews: A 3-dimensional assessment. *Am J Orthod Dentofacial Orthop* 2009;136:700-7.
9. Soheilifar S, Mohebi S, Ameli N. Maxillary molar distalization using conventional versus skeletal anchorage devices: A systematic review and meta-analysis. *Int Orthod* 2019;17:415-24.
10. Mao B, Tian Y, Xiao Y, Li J, Zhou Y. The effect of maxillary molar distalization with clear aligner: A 4D finite-element study with staging simulation. *Prog Orthod* 2023;24:16.
11. Castrolforio T, Parrini S, Rossini G, Nebiolo B, Gavetti F, Quinzi V,

- et al.* Upper first molar and second premolar distalization with clear aligner and interradicular skeletal anchorage: A finite element study. *Appl Sci* 2023;13:9695.
12. Hamanaka R, Yamaoka S, Anh TN, Tominaga JY, Koga Y, Yoshida N. Numeric simulation model for long-term orthodontic tooth movement with contact boundary conditions using the finite element method. *Am J Orthod Dentofacial Orthop* 2017;152:601-2.
 13. Alogaibi YA, Al-Fraidi AA, Alhajrasi MK, Alkhathami SS, Hatrom A, Afify AR. Distalization in orthodontics: A review and case series. *Case Rep Dent* 2021;2021:8843959.
 14. Ayidaga C, Kamiloglu B. Effects of variable composite attachment shapes in controlling upper molar distalization with aligners: A nonlinear finite element study. *J Healthc Eng* 2021;2021:5557483.
 15. Liu X, Cheng Y, Qin W, Fang S, Wang W, Ma Y, *et al.* Effects of upper-molar distalization using clear aligners in combination with class II elastics: A three-dimensional finite element analysis. *BMC Oral Health* 2022;22:546.
 16. Kawamura J, Park JH, Kojima Y, Tamaya N, Kook YA, Kyung HM, *et al.* Biomechanical analysis for total distalization of the maxillary dentition: A finite element study. *Am J Orthod Dentofacial Orthop* 2021;160:259-65.
 17. Vilanova L, Castillo AA, Bellini-Pereira SA, Henriques JF, Janson G, Garib D, *et al.* Three-dimensional changes after maxillary molar distalization with a miniscrew-anchored cantilever. *Angle Orthod* 2023;93:513-23.
 18. Saif BS, Pan F, Mou Q, Han M, Bu W, Zhao J, *et al.* Efficiency evaluation of maxillary molar distalization using invisalign based on palatal rugae registration. *Am J Orthod Dentofacial Orthop* 2022;161:e372-9.