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Research Protocol

Dentistry Section

Comparative Evaluation of Variability in Torque Expression in Maxillary Central Incisors with Different Column Angles using Brackets Placed at Different Levels in Class II Division 2 Malocclusion: A FEM Study

DIGVIJAY SHASHANK PRADHAN[1], RANJIT HARIDAS KAMBLE[2]

ABSTRACT

Introduction: Torque in the maxillary central incisors plays a critical role in determining the final treatment outcome for an orthodontic treatment of a malocclusion. The column angle of maxillary central incisors in Class II Division 2 malocclusion is increased as compared to individuals with other malocclusions. Variations in the column angle paired with bracket positioning can affect torque expression during orthodontic treatment. With variable column angles with brackets placed at different occlusogingival heights using Finite Element Model (FEM) analysis. The study will invariably provide a better understanding and clinical judgement of initial bracket positioning to consider the torque expression within the confines of alveolar complex whilst taking into account the altered crown root angle.

Aim: To evaluate and compare the expression of torque in maxillary central incisors with variable column angles by placing the brackets at different occlusogingival heights using FEM analysis.

Need of the study: The relationship between column angle morphology and torque mechanics has been poorly quantified, leaving clinicians without objective guidelines for bracket height selection in Class II Division two cases. Existing clinical observations suggest variability in torque response but lack controlled biomechanical evidence explaining how anatomical variations influence root behaviour. Treatment planning currently relies on empirical judgement, which can lead to inconsistent root positioning and prolonged finishing phases. FEM offers a way to generate predictable, reproducible biomechanical data that can help standardise torque mechanics for anatomically complex incisors. A systematic evaluation is required to establish evidence-based parameters for optimising torque expression when dealing with increased column angles.

Materials and Methods: This will be an observational, analytical finite element study conducted at the Department of Orthodontics and Dentofacial Orthopaedics, Sharad Pawar Dental College, Datta Meghe Institute of Higher Education and Research (DMIER), Wardha, Maharashtra, India. The study will be carried out over a period from 2nd July 2025 to 7th Febrauary 2027. A total of 9 FEMs were constructed, representing three column angles combined with three bracket positions. Three separate anatomic 3D FEMs of a maxillary central incisor with varying column angles will be constructed using Creo 10 software. An MBT prescription bracket with a slot size of 0.022×0.028 and a stainless-steel arch wire measuring 0.019×0.025 in cross-section will be placed in the bracket slot and secured using a stainless-steel ligature. A palatal root torque will be applied. A total of nine Simulations i.e., three simulations each for three different column angles (+9°, +12°, and+15°), with the brackets positioned at the incisal, middle, and gingival thirds of the clinical crown will be performed separately. The model will be discretised using a structured tetrahedral mesh, and the material properties will be assigned from well-established literature. Hyper Mesh software will be utilised for finite element analysis and biomechanical responses will be statistically analysed across the various simulation scenarios. Statistical significance will be evaluated using two-way Analysis of Variance (ANOVA).

Keywords: Angle's Class II Division 2 malocclusion, Bracket position, Crown–root, Finite element method, Occlusogingival

INTRODUCTION

Torque control of the maxillary central incisors is critical to the success of both functional and aesthetic objectives in orthodontic treatment, especially in Class II Division 2 malocclusions. This particular type of malocclusion is biomechanically challenging due to the retroclination of the maxillary central incisors, overbite, and increased column angles. Precise torque control is critical for the success of a perfect occlusion, facial aesthetics, and long-term stability of treatment results [1].

The column angle, which is a measure of the angular relationship between the crown and root of the maxillary central incisors, is greater in Class II division two cases as compared to other malocclusion types [2]. This increased column angle complicates the expression of torque and final root positioning, thereby making precise root positioning at the end of treatment more difficult. Retroclined incisors with greater column angles tend to have decreased intracortical bone space, and this could compromise palatal root movement and increase the risk of palatal cortical anchorage. Hence, as orthodontists authors need to control torque expression effectively while preventing unwanted effects such as root resorption, overloading and concentrated force application [2,3].

Class II Division 2 malocclusions have increased overbites, retroclination of the maxillary central incisors, proclination of the maxillary canines and lateral incisors, crowding, and a squared shape to the arch [4]. These features create conditions that make it more difficult to accomplish optimal torque compared to other malocclusion types. Torque is actually acts via the interaction between the bracket slot and arch wire; therefore, differences in bracket placement at different occlusogingival locations can lead to radically different treatment results [5,6]. Brackets placed too incisally could interfere with torque application, while more gingivally placed would most likely increase torque expression too much, thereby changing the final angulation of the maxillary central incisors [6,7].

Accurate bracket placement is needed for the expression of controlled torque. Owing to greater column angles in Class II Division two patients, bracket height placement must be done cautiously to allow for proper torque delivery without uncontrolled root movement.

Reflecting on the biomechanical status of torque control in maxillary central incisors in Class II Division two malocclusions orthodontists must keep in mind accurate bracket placement, proper arch wire selection, and torquing mechanics in class II Division two malocclusions with high column angle, deep overbite tendency, and insufficient space to deliver the best results. With proper control and sufficient torque expression, one can deliver a functional occlusion, improved aesthetic, and stable results [5,6].

Conventional orthodontic protocols largely rely on standardised bracket prescriptions which assume relatively uniform crown root morphology, this may not be appropriate for the teeth with increased column angles despite the clinical implications quantitative data evaluating the combined influence of column angle variability and bracket positioning on torque expression remain limited [2,3,8]. A direct clinical measurement of internal stress distribution is not feasible finite element analysis provides a controlled and reproducible method to investigate these biomechanical interactions therefore this study is needed to bio mechanically evaluate torque expression under varying column angles and bracket positions with the aim of guiding more individualised and predictable orthodontic treatment strategies [5-7].

Aim: To compare and evaluate the expression of torque in maxillary central incisors with variable column angles by placing the brackets at different occlusogingival heights using FEM analysis.

Objectives

- **Primary Objective:** To analyse and compare torque expression in maxillary central incisors with different column angles using FEM [5,6].

- **Secondary Objectives**

a) To evaluate the effect of three occlusogingival bracket positions on torque delivery.

b) To quantify resulting stress distribution patterns within the tooth, Periodontal Ligament (PDL), and supporting bone during palatal root torque.

c) To determine which combination of column angle + bracket height yields the most controlled and predictable torque expression.

Hypothesis

- **Null hypothesis:** There is no statistically significant difference in torque expression PDL stress or alveolar bone stress among FEMs of maxillary central in sizers with varying column angles and different occlusion gingival bracket positions when palatal root torque is applied

- **Alternate hypothesis:** There is a statistically significant difference in expression of torque, PDL stress and alveolar bone stress among FEMs of maxillary central incisors with varying column angles and different occlusal gingival bracket positioning when palatal root torque is applied.

REVIEW OF LITERATURE

Several studies have evaluated the morphological and biomechanical factors influencing torque expression in maxillary incisors Shailaja AM et al., [2]. Assessed the column angle of maxillary central incisors across different skeletal malocclusions and reported significantly increased column angles in Class 2 Division 2 cases highlighting the potential challenge in achieving controlled root movement in such patients [2].

McIntyre and Millett analysed crown root morphology of maxillary central incisors and demonstrated considerable variation in crown root angulation suggesting that standardised bracket prescriptions may not consistently deliver intended torque across different tooth morphologies [3].

Papageorgiou SN et al., used finite element analysis to evaluate torque differences related to tooth morphology and bracket positioning concluding that both factors significantly influenced torque expression and stress distribution within the PDL they are findings emphasised the biomechanical importance of individualised bracket placement [5].

Sardarian A et al., investigated the effect of occlusogingival bracket positioning on torque expression using FEM and reported increased torque expression and PDL stress with more ginjupalli positioned brackets this study highlighted the sensitivity of torque delivery to occlusion gingival bracket placement [6].

Sivanandam M et al., conducted a finite element analysis comparing torque expression using different bracket prescriptions placed at varying ground levels and found significant variations in stress distribution and tooth displacement depending on the bracket position their results supported the need for careful bracket positioning during clinical practice [7].

Joch A et al., evaluated the dimensional accuracy of orthodontic bracket slots and arch wires and reported clinically relevant variations between manufacturer-stated and actual dimensions. They concluded that slot-wire clearance significantly affects third-order torque expression, emphasising that even with idea l bracket positioning, torque delivery may be compromised due to mechanical play within the appliance system [9].

Papageorgiou SN et al., analysed the torquing efficiency of square and rectangular stainless steel arch wires engaged in 0.018- and 0.022-inch bracket slots. Their findings demonstrated that torque expression is affected by archwire dimension, bracket slot size, and wire-slot engagement, reinforcing the importance of considering appliance-related variables when evaluating torque biomechanics using FEMs [10].

MATERIALS AND METHODS

This will be an observational, analytical finite element study conducted at the Department of Orthodontics and Dentofacial Orthopaedics, Sharad Pawar Dental College, Datta Meghe Institute of Higher Education and Research (DMIER), Wardha, Maharashtra, India. The study will be carried out over a period from 2nd July 2025 to 7th Febrauary 2027. Ethical approval for the study was obtained from the Institutional Ethics Committee of Datta Meghe Institute of Higher Education and Research (DMIER) (IEC Reference No: DMIHER(DU)/IEC/2025/540). No direct patient recruitment or intervention was performed; hence, informed consent was not applicable.

Inclusion criteria:

- Morphological characteristics representative of Class II Division two malocclusion;
- Maxillary central incisor with a column angle ≥ 9°;
- Fully developed permanent maxillary central incisor.

Exclusion criteria:

- Presence of root dilaceration or developmental anomalies;

- Evidence of trauma, resorption, or previous orthodontic treatment;
- Craniofacial anomalies affecting maxillary incisor morphology.

Sample size: A total of 9 FEMs were constructed, representing three column angles combined with three bracket positions [5-7].

Study Procedure

A 3D FEM of a maxillary central incisor with an increased column angle will be constructed using Creo 10 modeling software. For better dimensional accuracy of the model, a reference Cone Beam Computed Tomography (CBCT) scan of an incisor with an increased column angle would be referred. The aforementioned Conical Beam Computed-tomography (CBCT) scan will be selected from retrograde data of previously scanned patients following inclusion and exclusion criteria, referred from the Department of Orthodontics and Dentofacial Orthopaedics Sharad Pawar Dental College Wardha, Maharashtra, India Sawangi [6,7].

After independently designing the McLaughlin, Bennett, and Trevisi (MBT) bracket of central incisor with dimensions of 0.022×0.028" slot will be used and a stainless-steel wire of rectangular cross-section 0.019×0.025 a structured tetrahedral mesh will be assigned to all 3D models [5,7,10].

The aforementioned wire will be engaged in the bracket slot and secured with a stainless-steel ligature wire. A palatal root torque is applied to the secure wire.

The aforementioned process will be simulated for 3 different column angles {+9degrees, +12 degrees and +15 degrees} each with three different bracket positions {placed in the incisal, middle, and gingival thirds respectively [5,6].

Material properties will be assigned using Young's modulus and Poisson's ratio values from the literature. Then boundary conditions will be applied to the model, which is defined based on the nature of the modeling system. Material properties for the FEM will be assigned using Young's modulus and Poisson's ratio values reported in previously published orthodontic finite element studies. Poisson's ratio values of 0.30 for stainless steel (archwire and bracket), 0.30 for alveolar bone, and 0.31 for dentin will be adopted, in accordance with the material property tables reported by Papageorgiou SN et al., Sivanandam M et al., and Sardarian A et al., [6]. These values have been consistently used across orthodontic finite element analyses and provide a standardised and reproducible basis for evaluating torque expression and stress distribution within the tooth–periodontium complex [6,7,11].

Hypermesh software will be used for the FEM analysis. Forces will be applied at different Geometric points. The raw data will be statistically compared between different simulations [5-7].

Primary and Secondary Outcomes

Primary outcome: The primary outcome of the study will be the magnitude and pattern of torque expression in the maxillary central incisor under palatal root torque across different finite element simulation conditions. Torque expression will be evaluated by assessing the angular displacement and rotational behaviour of the tooth in response to applied torque forces among models with varying column angles (+9°, +12°, and +15°) and different occlusogingival bracket positions (incisal, middle, and gingival thirds of the clinical crown).

This outcome will be selected as the primary endpoint because torque expression directly influences the accuracy of root positioning during orthodontic finishing and is expected to vary with crown–root morphology and bracket placement.

Secondary Outcomes: The secondary outcomes of the study will include the stress distribution within the PDL, the stress distribution within the alveolar bone, and the pattern of tooth displacement associated with torque application.

Stress distribution within the PDL will be analysed to identify areas of stress concentration which will help to evaluate the biomechanical response of the supporting periodontal structures during torque delivery. Alveolar bone stress will be assessed to determine the transmission of orthodontic forces to the surrounding bone, particularly in relation to potential palatal cortical engagement in models with increased column angles.

The pattern of tooth displacement will also become assessable.

The direction and magnitude of movement associated with different bracket positions and column angles can be gauged. This will provide a comprehensive biomechanical understanding of torque delivery and its effects on the tooth-periodontium complex. The GANTT Chart depicting the planned timeline of the FEM study have been depicted in [Table/Fig-1].

STATISTICAL ANALYSIS

All quantitative data obtained from the finite element simulations will be recorded and tabulated using Microsoft Excel. Statistics for mean and standard deviation, will be calculated for torque expression, PDL stress, alveolar bone stress, and tooth displacement across all simulation models. Inferential statistical analysis will be performed using two-way ANOVA to evaluate the independent effects of column angle and occlusogingival bracket position, as well as their

Study activity	Jan–Mar 2025	Apr–Jun 2025	Jul–Sep 2025	Oct–Dec 2025	Jan–Mar 2026	Apr–Jun 2026	Jul–Sep 2026	Oct–Dec 2026	Jan 2027
Literature review and protocol finalisation	✔								
Ethical approval (IEC clearance)	✔								
Reference CBCT data identification and screening		✔							
3D geometric modeling (tooth, PDL, bone)		✔	✔						
Bracket and archwire modeling			✔						
Meshing and material property assignment			✔	✔					
Boundary conditions and force application				✔					
FEM simulations (all 9 models)				✔	✔				
Data extraction and validation					✔				
Statistical analysis					✔	✔			
Interpretation of results						✔			
Thesis writing (Results and discussion)							✔		
Thesis revision and pre-submission corrections								✔	
Thesis submission									✔

[Table/Fig-1]: GANTT chart depicting the planned timeline of the finite element study.

interaction effect, on the measured biomechanical outcomes. All statistical analyses will be carried out by using appropriate statistical software, and the level of statistical significance will be set at $p<0.05$. The statistical analysis will be used to compare differences between finite element simulation conditions and will not be intended for population-based inference.

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PARTICULARS OF CONTRIBUTORS:

1. Postgraduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Sharad Pawar Dental College, Datta Meghe Institute of Higher Education and Research, Wardha, Maharashtra, India.
2. Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, Sharad Pawar Dental College, Datta Meghe Institute of Higher Education and Research, Wardha, Maharashtra, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Digvijay Shashank Pradhan,
Postgraduate Student, Department of Orthodontics Sharad Pawar Dental College
DMIHER Sawangi Meghe, Wardha-442001, Maharashtra, India.
E-mail: digvijaypradhan1999@gmail.com

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