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Original Article

Comparative Effectiveness of Sliding Mechanics and Continuous Loop Mechanics: During En-Mass Retraction-Finite Element Method Study

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Abstract

Introduction: Bimaxillary dentoalveolar protrusion is considered one of the major chief complaints of adult patients seeking orthodontic treatment. Tooth movement in extraction cases can be achieved efficiently by both friction as well as frictionless mechanics. Application of finite element method (FEM) has revolutionized dental biomechanical research. FEM is, therefore, ideally suited to evaluate this structural behavior of teeth.

Aim of Study: To investigate and compare the effectiveness of en-mass retraction using sliding mechanics and continuous loop mechanics using FEM.

Materials and Methods: A computed tomography scan of maxillary teeth and adjacent region of a 24-year-old male patient with class I bimaxillary protrusion was used. Six 3D geometric models were constructed, then a finite element model was constructed. Displacement of anterior and posterior segments for three different force values of 150 g, 200 g, and 250 g in both group I (sliding) and group II (loop mechanics) was determined.

Results: Loop mechanics (−0.001 mm–−0.0017 mm) was superior to sliding mechanics (−0.0015 mm–−0.0033 mm) in terms of anchorage control for all three force levels. More anterior retraction was seen in loop mechanics (0.0022 mm–0.0045 mm) as compared to sliding mechanics (0.0033 mm–0.0052 mm).

Conclusions: It was observed that loop mechanics was superior to sliding mechanics in terms of anchorage control and anterior retraction. All values increase as we move toward a higher force subgroup.

Key words: Anchorage loss, Anterior retraction, Loop mechanics, Sliding mechanics

INTRODUCTION

In orthodontics, protrusion of the maxillary and mandibular incisors with increased procumbency of the lips is considered one of the major chief complaints of adult patients. This condition is known as bimaxillary dentoalveolar protrusion.[1] The usual objective of treatment in such a condition is the retraction of anterior teeth with a resultant decrease in soft-tissue convexity.[2]

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And so, the treatment of choice for these patients is to extract the first premolars.

Tooth movement in four premolar extraction cases can be achieved by both friction as well as frictionless mechanics with respective advantages and disadvantages of each technique.

Despite the large number of studies dealing with the mechanics of space closure, not enough evidence was found in the orthodontic literature regarding the best technique for anterior teeth retraction. One of the methods is the finite element technique. The history of finite element analysis dates back to 1943, when R. Courant first developed this technique.[3]

This offers accurate modeling of the tooth and its surrounding structures with its complicated geometry.

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It makes it possible to analytically apply various forces at any point, in any direction, and also quantitatively and qualitatively assess the distribution of such forces through the alveolar bone, periodontal ligament, and tooth.[4]

Hence, the aim of the present study is to investigate and compare the effectiveness of en-mass retraction using sliding mechanics and continuous loop mechanics.

MATERIALS AND METHODS

The present finite element method (FEM) study was carried out in the Department of Orthodontics and Dentofacial Orthopaedics, Desh Bhagat Dental College, Mandi Gobindgarh, Punjab. For this study, a computed tomography (CT) scan of a 24-year-old male patient with class I bimaxillary protrusion was used. Six FEM models were prepared. The analytical model used in this study was developed from CT scan images of an adult human skull and the digital imaging and communications in medicine format were used as input in the study. Only Maxilla was modeled using MIMICS and Hypermesh FEM software.

In the present study, six different finite element models of maxilla with right second molar to left second molar teeth were studied to evaluate and compare the effectiveness of en-mass retraction using three models with 0.019" × 0.025" stainless steel archwire for sliding mechanics (Group I) Figure 1, and continuous loop mechanics using three models with 0.019" × 0.025" TMA archwire for omega loop (Group II) Figure 2, 45° α and β gable bends were given in omega loop group. Finit element model is a representation of geometry in terms of a finite number of elements and their connection points known as nodes [Table 1].

Finite element analysis was done with three variable ranges of forces 150 g, 200 g, and 250 g.

Inclusion Criteria

- Patient without any missing teeth
- No malformed teeth
- No periodontal disease
- Maxillary first bicuspid extraction.

The range of displacements was obtained in different ranges of colors, extending from blue to red. Maximum movement displays crown tip movement, and minimum movement displays root apex movement.

Displacement of Teeth

Displacements were calculated in three directions: X, Y, and Z

X- Direction – It is the movement in the transverse plane

Y- Direction – It is the movement in the sagittal plane

Z- Direction – It is the movement in the vertical plane.

Directions to be Followed

- For anterior teeth:-+Y means lingual, -Y means buccal, X is the lateral direction
- For posterior teeth:-+X means Lingual, -X means buccal, +Y means distal, -Y means mesial
- Both teeth:-+Z means intrusion, and -Z means extrusion.

We Have to Understand the Movement

- w.r.t X-direction (red arrow)
- w.r.t Y-direction (green arrow)
- w.r.t Z-direction (blue arrow).

These results were interpreted by various colors, which show us the maximum (movement/displacement of the crown tip) and minimum (movement/displacement of root tip) values in their respective directions. Results were interpreted in all three axes [Tables 2-6].

DISCUSSION

The present study aimed to investigate and compare the effectiveness of en-mass retraction using sliding mechanics and continuous loop with three variable force levels (150 g,

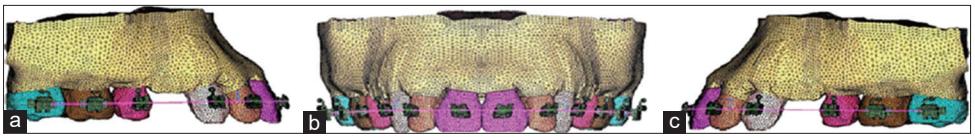

Figure 1: Finite element model of maxilla with 0.019" × 0.025" stainless steel wire. (a) Right buccal view, (b) Frontal view, (c) Left buccal view

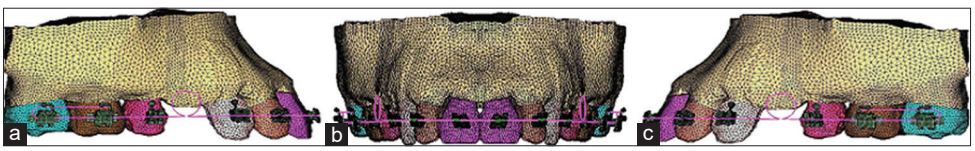

Figure 2: Finite element model of maxilla with omega loop in position. (a) Right buccal view, (b) Frontal view, (c) Left buccal view

Table 1: Details of nodes and elements

Part name	No. of nodes	No. of elements
Cortical bone	22308	67328
Cancellous bone	37107	150786
Teeth	22308	67328
PDL	25600	75000
Brackets	14604	45791
Wire and hooks	221	220

Table 2: Comparison of both retraction groups (Y-axis)

Mechanics displacement	Subgroup 150 g				Subgroup 200 g				Subgroup 250 g			
	Sliding		Loop		Sliding		Loop		Sliding		Loop	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Central Incisor	0.0022	0.003	0.0033	0.0042	0.0028	0.0035	0.0036	0.0044	0.0031	0.0040	0.0039	0.0049
Lateral Incisor	0.003	0.0036	0.0033	0.0043	0.0035	0.004	0.0035	0.0044	0.0038	0.0045	0.0040	0.0050
Canine	0.003	0.0036	0.0033	0.0043	0.0037	0.0041	0.0035	0.0045	0.0038	0.0045	0.0041	0.0052
2nd Premolar	−0.0015	−0.002	−0.001	−0.0015	−0.00151	−0.0021	−0.0013	−0.0015	−0.00156	−0.0028	−0.0014	−0.00165
1st Molar	−0.001516	−0.00215	−0.0011	−0.0015	−0.00152	−0.0024	−0.0011	−0.00151	−0.00163	−0.0033	−0.0012	−0.0017
2nd Molar	−0.00151	−0.0021	−0.001	−0.0015	−0.00154	−0.0022	−0.0011	−0.0015	−0.00162	−0.0032	−0.0011	−0.00154

Table 3: Results for X-axis (sliding mechanics)

Displacement region	Subgroup 150 g		Subgroup 200 g		Subgroup 250 g	
	Displacement		Displacement		Displacement	
	Max	Min	Max	Min	Max	Min
Central Incisor	−0.000	0.000	−0.000	0.000	−0.000	0.000
Lateral Incisor	−0.000	0.000	−0.0001	0.000	−0.00011	0.000
Canine	−0.0005	0.000	−0.00056	0.0001	−0.0008	0.00014
2nd Premolar	−0.0002	0.000	−0.00021	0.000	−0.0003	0.000
1st Molar	0.0005	0.000	0.00052	0.000	0.0007	0.000
2nd Molar	0.00015	0.000	0.00018	0.000	0.00025	0.000

Table 4: Results for X-axis (loop mechanics)

Displacement region	Subgroup 150 g		Subgroup 200 g		Subgroup 250 g	
	Displacement		Displacement		Displacement	
	Max	Min	Max	Min	Max	Min
Central incisor	−0.000	0.000	−0.000	0.000	−0.000	0.000
Lateral incisor	−0.0001	0.000	−0.00018	0.00010	−0.00024	0.00014
Canine	−0.0006	0.0002	−0.0007	0.00021	−0.001	0.00023
2nd Premolar	0.00031	−0.000	0.00035	−0.000	0.0005	−0.000
1st Molar	0.0006	−0.000	0.00062	−0.000	0.00079	−0.000
2nd Molar	0.00020	0.000	0.00030	0.000	0.00040	0.000

Table 5: Results for Z-axis (sliding mechanics)

Displacement region	Subgroup 150 g		Subgroup 200 g		Subgroup 250 g	
	Displacement		Displacement		Displacement	
	Max	Min	Max	Min	Max	Min
Central incisor	−0.00034	−0.0002	−0.00038	−0.00028	−0.00045	−0.0003
Lateral incisor	−0.0003	−0.000	−0.00035	−0.000	−0.00042	−0.000
Canine	−0.0004	−0.000	−0.0005	−0.000	−0.0006	−0.000
2nd Premolar	0.0002	0.000	0.00021	0.000	0.00022	0.000
1st Molar	−0.0002	0.0002	−0.00022	0.00022	−0.00024	0.00024
2nd Molar	−0.00016	−0.000	−0.00017	−0.000	−0.00018	−0.000

Table 6: Results for Z axis (loop mechanics)

Displacement region	Subgroup 150 g		Subgroup 200 g		Subgroup 250 g	
	Displacement		Displacement		Displacement	
	Max	Min	Max	Min	Max	Min
Central incisor	−0.00020	−0.00015	−0.00034	−0.00016	−0.00040	−0.00020
Lateral incisor	−0.00024	−0.000	−0.00032	−0.000	−0.00040	−0.000
Canine	−0.0003	0.000	−0.0004	0.000	−0.0005	0.000
2nd Premolar	0.00018	−0.000	0.00019	−0.000	0.0002	−0.000
1st Molar	−0.0001	0.000	−0.00014	0.000	−0.00016	0.000
2nd Molar	−0.000	−0.000	−0.000	−0.000	−0.00010	−0.000

200 g, 250 g) through FEM. Different force values were suggested, ranging from 150 g to 260 g, by different authors, so this range was studied in the present study.

The aims and objectives of the study were to compare the effectiveness of en-mass retraction and anchor loss [Table 2] between sliding and continuous loop mechanics. The anchor loss showed a minor difference in the loop as well as sliding mechanics. In loop mechanics, anchor loss was less Martins *et al*.[5] using a TMA T loop with a 45° gable bend found controlled tipping of maxillary canines and molars during retraction with a range of canine retraction of 1mm was seen in comparison to 0.3 mm of mesial molar movement.

This might be due to the α and β gable bends of 45° that were incorporated into the loop model, leading to an increase of M\F ratio. Loop mechanics was more effective than sliding mechanics in reducing the tipping. Singhal *et al*.[6] compared to sliding and loop mechanics found a more bodily movement of teeth in loop mechanics and more tipping in sliding mechanics.

By loop mechanics bodily movement of anterior teeth instead of tipping movement during retraction with better anchorage control was observed. Choi *et al*.[7] used off-center T loop mechanics for anterior retraction in the maxilla and found little molar movement and controlled tipping of anterior teeth. More tipping was seen for an anterior segment with less tipping seen in the posterior area. An increase in tipping was seen when the force magnitude was increased. Both sliding as well as loop mechanics are superior in some properties with respect to each other.

Limitations of the Study

The results of finite element analysis must be interpreted with great care. The accuracy of the analysis depends on the modeling structures as closely as possible to the actual. However, a certain amount of approximation manifested chiefly in terms of type and number of arrangement of elements is inevitable in complex designs.

The following conclusions were drawn from the study:

- It was observed that loop mechanics was superior to sliding mechanics in terms of anchorage control
- More anterior retraction was seen in loop mechanics as compared to sliding mechanics. Among the three force levels, more retraction was reported with 250 g of force for both groups
- More tipping and extrusion were seen in sliding mechanics. Tipping and extrusion were more with a force level of 250 g when compared to a force level of 150 g and 200 g for both groups.

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