Original Article

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A Comparative Evaluation of Effects of Micro-osteoperforations on Canine Retraction Using Finite Element Analysis: An *In Vitro* Study

Rama Bharat Samgir[1], Sangmesh Fulari[2], Jiwanasha Agrawal[3], Manish Agrawal[2], Lalita Nanjannawar[2], Vishwal Kagi[4]

[1]Post-graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth Dental College and Hospital, Sangli, Maharashtra, India, [2]Associate Professor, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth Dental College and Hospital, Sangli, Maharashtra, India, [3]Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth Dental College and Hospital, Sangli, Maharashtra, India, [4]Lecturer, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth Dental College and Hospital, Sangli, Maharashtra, India

Abstract

Objective: The aim of this study is to evaluate the effects of modified corticotomy procedures on canine retraction and compare it with the conventional method using finite element analysis.

Materials and Methods: Three-dimensional finite element method was used to simulate canine retraction after modified corticotomy procedures in sliding mechanics after first premolar extraction. Retractive force of 200 g was applied, and the amount of canine retraction was measured in both micro-osteoperforation and vertical groove model and compared with the conventional model.

Result: Vertical groove model shows the maximum amount of canine retraction followed by micro-osteoperforation model and least with the conventional model.

Conclusion: Modified corticotomy procedures have been proven to be an efficient way of accelerating orthodontic tooth movement as it reduces cortical bone resistance.

Key words: Conventional model, Micro-osteoperforations model, Vertical groove model

INTRODUCTION

Lifestyle of today's era demands a time-valued perception of everything which is also applicable in orthodontics. Patient compliance is the driving force to accomplish the treatment at its finest. Patient's demands for shorter orthodontic treatment duration are on the rise. Orthodontists have been under constant pressure to explore various methods of accelerating tooth movement. One of the most common tooth movements inS orthodontic treatment is a canine retraction. At present, conventional fixed orthodontic treatment requires about 1–2 years.[1] More time is required for extraction cases, such as for adult patients, which is a great concern and poses a high risk of caries,[2] external root resorption.[3,4] Thus, accelerating orthodontic tooth movement and the resulting shortening of the treatment duration would be beneficial. Many researchers have utilized different biochemical methods involving medications to improve the speed and quality of orthodontic treatment, but the systemic influence on the body's metabolism makes this difficult to apply in orthodontics. Recently, investigators have begun studying local techniques for stimulating better orthodontic tooth movement. Surgically aided rapid tooth movement has become one of the novel techniques for accelerating canine retraction. Systemic review by Long *et al.*, concluded that among various methods used for accelerating orthodontic tooth movements, corticotomy surgical method was safe, efficient and time reducing procedure. The original corticotomy technique described by Kole included a combined interradicular corticotomy and supra-apical

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Corresponding Author: Dr. Rama Samgir, Department of Orthodontics and Dentofacial Orthopaedics, Bharati Vidyapeeth Dental College and Hospital, Sangli - 416 414, Maharashtra, India. Phone: +91-8149435609/8208332275. E-mail: ramas1212@gmail.com

osteotomy. Biologic tooth movement[5] can be achieved with conventional orthodontic treatment techniques, but the canine retraction phase usually lasts for 6–8 months.

Until now, these research modalities and techniques for accelerating canine retraction have been applied in animal experiments and clinical case reports. Finite element analysis has become a powerful tool for dental biomechanical research due to its increased availability, capacity and ease of use of computer software in biologic modeling. It can be considerably effective and most importantly, non-invasive way and helps us for simulating complicated procedures which ultimately gives right path in treatment planning.[6]

Among the various ways of accelerating canine retraction, corticotomy procedures recently gaining popularity.[7] Conventional corticotomy contained the raising of the flap after which vertical grooves or a number of perforations were made on the buccal as well as the palatal aspects followed by bone grafting. This current study gives more emphasis on a modified version of corticotomy for accelerating the canine movements with a reduction in micro-osteoperforations to only three in number in one finite element method (FEM) model and vertical groove on second FEM model which is then compared with conventional FEM model.

Aims and Objectives

Aim

The aim of the study was to evaluate the effects of modified corticotomy on canine retraction and compare it with the conventional method using finite element analysis.

Objective

1. To measure the amount of canine retraction following micro-osteoperforations (3 circular perforations) and compare it with the conventional method using finite element analysis.
2. To measure the amount of canine retraction following micro-osteoperforations (vertical groove) and compare it with the conventional method by finite element analysis.

MATERIALS AND METHODS

Three-dimensional (3D) finite element model was constructed, including maxillary teeth, periodontal ligament (PDL), alveolar bone, brackets, wire, and bands in which first premolars were extracted.

Although PDL thicknesses differ according to age, position, and individual variations, the thickness of the PDL was considered to be consistently 0.25 mm. The 3D finite element models of the alveolar bone were fabricated to fit the teeth and the PDL, and the thickness of cortical bone was considered to be 2 mm.[6-9]

In this study, the orthodontic force was applied to three FEM models (ANSYS R14.5) which simulated the canine retraction. The forces were applied to the surfaces of the teeth, mesiodistally, as in normal clinical practice. In this study, we defined conventional canine retraction model as model 1. The numbers of nodes and elements of the initial model are shown in Table 1. Construction of second and third model was same as like model 1 to compare the amount of canine retraction. On model 2, three micro-osteoperforations were made distal to canine in extraction space at the level of canine root apex, 2 mm apical to the marginal alveolar bone and in between these two perforations.[10] In model 3, the vertical groove was made along the long axis of canine root in the extraction space [Figures 1-4]. After removing the barrier of cortical bone which was around 2 mm deep and 1.5 mm, wide immediate orthodontic force was applied.[8] Optimal force for canine retraction is 200 g which has proven sufficient amount of force to maximize the rate of canine retraction without any ill effects on tooth itself and surrounding structures too.[11] After application of force amount of canine retraction was measured on all three models. Results are shown in Table 2.

RESULTS

Immediately after loading of the retraction forces of 200 g between the crown of the first molar and the canine, the initial displacement of the canine was highly concentrated in the distal area of the crown in all three models.

The results of this study, which showed stress distribution along the root, PDL, and alveolar bone, provided insight into clinical observations.[6] Compared with the conventional method of canine retraction, we found that model 3 (vertical

Table 1: Number of nodes and elements generated for initial model

Models	Number of nodes	Number of elements
Cancellous bone	69.897	41.814
Cortical bone	118.762	68.648
Canine	7.293	4.181
Second premolar	3.933	2.241
First molar	5.961	3.497
PDL of canine	17.383	8.584
PDL of second premolar	11.482	5.645
PDL of first molar	18.873	9.306

PDL: Periodontal ligament

Table 2: Deformation in the canine with various arrangements during retraction

Method	Deformation (mm)
Conventional method	0.303
With Micro-osteoperforations	0.382
With groove	0.443

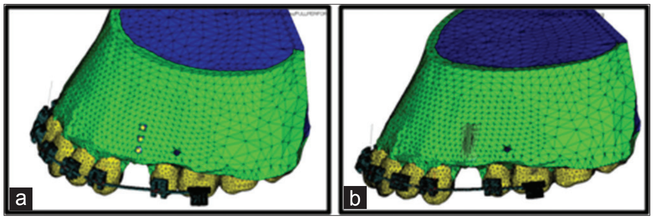

Figure 1: (a) Model 2 showing micro-osteoperforations, (b) Model 3 showing vertical groove

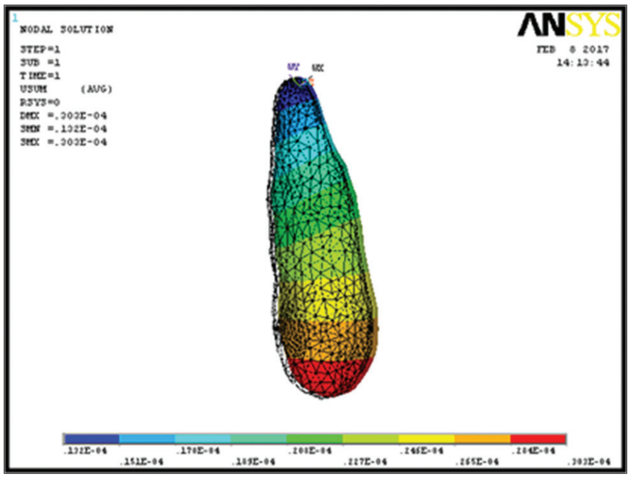

Figure 2: Deformation plot for intact teeth of conventional model (model 1)

groove) showing the maximum amount of canine retraction followed by model 2 (3 micro-osteoperforations).

DISCUSSION

Orthodontic tooth movement is a biological process characterized by sequential reactions of periodontal tissue against a biomechanical force system. It is also a process in which the application of a mechanical force induces alveolar bone resorption on the pressure side and alveolar bone deposition on the tension side.[12] The orthodontic force system is a complicated three-dimensional system which is difficult to evaluate in clinical conditions, and orthodontic force plays an important role in the entire biomechanical process during tooth movement. In our study, it was found that the effects of force application would be changed when the force-loading environment was changed. For accelerating canine retraction speed, periodontal tissue, especially hard tissue such as alveolar bone around the canine, is the most important source of resistance.[6]

In this study, the orthodontic force was applied to three FEM models which simulated two different surgical interventions and one conventional treatment for canine retraction. Stress distribution and deformation on the root, PDL, and cortical bone were evaluated.[6]

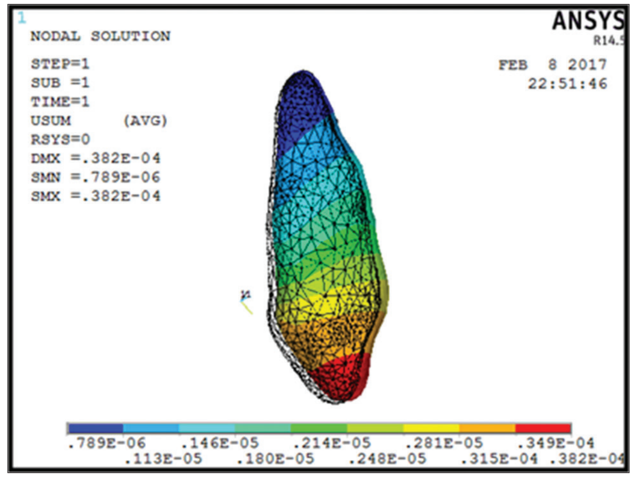

Figure 3: Deformation plot of micro-osteoperforations, model 2 (maximum deformation: 0.0000382 mm)

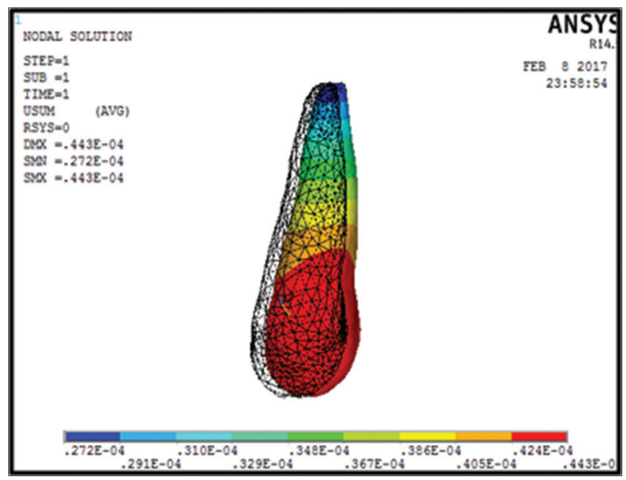

Figure 4: Maximum deformation with grooved configuration: (0.0000443 mm), model 3

On the basis of previous studies, resistance to tooth movement is increased when the roots are torqued lingual or buccal. This principle was used by Rickets[13] and is called cortical anchorage. In general, cortical bone offers more resistance to resorption. The cortical bone could also block tooth movement in most cases in orthodontic treatment. In this study, we observed the distribution of stress on the buccal side of cortical bone around the canine root, which implied that the cortical bone on the buccal side of the canine was also the source of resistance to canine movement. That explained the principle of surgical procedures of corticotomy which is intentional cutting of cortical bone leaving intact medullary vessels results in osteopenia which is temporary but reversal loss in bone density. Taking advantage of osteopenia tooth movement is accelerated. However, based on our results, modified corticotomy with vertical groove shows faster canine retraction. This procedure would minimize surgical injury and reduce complications for patients. Furthermore, canine retraction with only 3 micro-osteoperforations shows faster tooth movement when compared to conventional method of canine retraction which is also suggestive of reduced resistance of cortical bone.

Anchorage control should be considered when accelerated tooth movement is necessary. An obvious strategy for anchorage control would be to concentrate the force needed to produce tooth movement where it was desired and then to dissipate the retraction force in the PDL of anchor teeth as much as possible. In this study, the value of maximum equivalent (von Mises) stress in the PDL of the first molar in two models was a surgical reduction of resistance to a level lower than in the canine. Further, the value of total deformation of the first molar in models 2 and 3 was far below that of the canine at the initial stage of force loading.

This indicated that reducing resistance by modified corticotomy procedures to accelerate canine retraction was a safe way to protect anchorage and would not reduce anchorage during canine retraction which may ultimately shorten orthodontic treatment duration.

This study and others have demonstrated that FEM provides a solid, workable foundation for modeling a system of orthodontic tooth movement1. The chief advantage of FEM is that it can be magnified nearly infinitely, in terms of both the actual volumetric construction itself and the mathematical variability of its material parameters. However, as with any theoretical model of a biological system, there are limitations. The mechanical behavior of the materials was assumed to be linear elastic (homogeneous and isotropic), and the value of each material was inferred from previous reports. Cortical bone thickness and cancellous bone quality were not incorporated into the analysis, to prevent bone stress from being dominated by the bone quality and potentially confounding the outcomes related to other relevant factors. In addition, the stress analysis of soft tissues was not considered in this study. The soft tissues, such as gingival and facial muscles, are also sources of resistance for blocking rapid tooth movement. Regardless of these limitations, we integrated a finite element approach with variable analysis to investigate the comparative influences of resistance source, the pathway of canine movement, and different types of surgeries for rapid canine retraction by reducing resistance.[14-16]

CONCLUSION

This study was aimed toward evaluating the effects of modified corticotomy procedures on canine retraction and compare it with the conventional method of canine retraction with FEM study.

In this study, compared with dentoalveolar distraction osteogenesis, periodontal distraction aided by the surgical undermining of the interseptal bone would reduce the resistance in the pathway of canine movement more effectively to accelerate canine retraction speed in rapid canine movement during orthodontic treatment. The results indicated that rapid canine retraction aided by the surgical reduction of resistance might create side effect: (1) It might lead to canine rotation during distalization.

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