Increasing the vertical intrusive force is one of the methods routinely used to prevent the uncontrolled tipping and obtain bodily tooth movement in labial orthodontics (LaO). Intrusive forces act differently in both techniques because of the different location of force vectors in relation to the center of resistance. Increasing the vertical intrusive force is one of the methods routinely used to prevent the uncontrolled tipping and obtain bodily tooth movement in LaO. However, its effects in lingual technique need to be investigated to derive at an optimal treatment mechanics.

It is also believed that to obtain an adequate torque control in LiO, higher intrusive forces are required than that required in conventional labial mechanics.

Lingual orthodontics (LiO) has grown rapidly in the past few years and today is as popular as the labial technique among orthodontists and patients all over the world. However, there are many clinical and biomechanical differences between the two techniques.\(^1\)\(^-\)\(^3\) Hence, simply following the conventional labial mechanics blindly and applying it in LiO can be inappropriate and may result in a less than optimal treatment results.

Context: Biomechanical differences between lingual and labial orthodontics (LiO and LaO).

Aims: To investigate the effects of intrusive forces in lingual technique during retraction treatment mechanics.

Settings and Design: Intrusive forces act differently in both techniques because of the different location of force vectors in relation to the center of resistance. Increasing the vertical intrusive force is one of the methods routinely used to prevent the uncontrolled tipping and obtain bodily tooth movement in LaO. However, its effects in lingual technique need to be investigated to derive at an optimal treatment mechanics.

Subjects and Methods: Finite element method which has been successfully used to simulate tooth movement and optimize orthodontic mechanics effectively was used in this study. An accurate model of the upper central and lateral incisors with the surrounding structures was developed, and the “ANSYS” version 7.0 software was used for analysis.

Results: Intrusive forces as high as 3.6N was required to obtain translation in LiO that too in an undesirable direction. Efforts to obtain torque control by increasing the intrusive force only would not be successful.

Conclusion: Forces that produce a translation in LaO tends to produce uncontrolled tipping in lingual technique. To obtain adequate torque control in lingual technique, a combination of the reduction in horizontal retraction forces, increased lingual root torque application, and increase in vertical intrusive forces is desirable.

Key words: Finite element method, intrusive forces, lingual orthodontics
Thus, the purpose of this study was to investigate and compare the effects of intrusive forces in lingual technique during retraction treatment mechanics.

**SUBJECTS AND METHODS**

In this study, the finite element method (FEM) model of the upper central and lateral incisor was developed using computed tomography scan images from a dry human skull. The dimensions for the incisors were taken from dental anatomy textbooks.\(^4\)

The FEM model was a four-noded tetrahedral model with 148,440 nodes and 33,169 elements [Figure 1].

The software used for the present study was “ANSYS” (ANSYS, Inc., Canonsburg, Pennsylvania, USA) version 7.0 which is a three-dimensional interactive color graphic program for geometric and finite modeling.

After making the three-dimensional model of the central and lateral incisors with the alveolar bone and periodontal ligament (PDL), material properties taken from previous studies [Table 1] were applied to the model. All materials were assumed to be isotropic and elastic for simplification of the study.

Boundary conditions were defined at all peripheral nodes of the bone with 0° of movement in all directions.\(^5\)

**Experiment**

The force application nodes were kept at the same horizontal level.

*Labial loading*
- Central incisors - 4.45 mm
- Lateral incisors - 4.23 mm.

*Lingual loading*
- Central incisors - 3.75 mm
- Lateral incisors - 3.18 mm.

Three types of forces were applied to obtain bodily movement. Loads were applied on the labial surface first [Figure 1].
- Retraction (Fx)
- Vertical (Fy)
- Rotational (Fz).

The same forces were applied to the lingual surface. Then, keeping the Fx and Fz constant, varying forces of Fy were applied on the lingual surface till bodily tooth movement was obtained.

From previous studies, it was understood that the distribution of stress – strain and the root displacement of the central and lateral incisors follow a similar nature. Hence, to simplify the process, we used the central incisor to compare the biomechanical differences.

The analysis was focused on the following:
- Maximum principal stresses (s1)
- Minimum principal stresses (s3)
- Maximum principal strains (e1)
- Minimum principal strains (e3) on the PDL
- Total displacement (d) of the central incisor.

**RESULTS**

From our preexperiments, it was derived that application of load Fx = 1N, Fy = 0.65N, and Fz = 7 N/mm from labial surface (LaO) produced near translation as shown in the stress distribution pattern, [Figure 2a-c].

On labial surface of the PDL, the tensile stresses were produced and were distributed uniformly all throughout except in the mid-root to apical third where some compressive stress was seen.

On the lingual side, compressive stress was produced and distributed evenly throughout the surface, except in the mid-root area where tensile stress was found. This indicated that the tooth movement was near translation.

In comparison when the same load was applied from the lingual surface (LiO) the stress distribution showed lingual tipping of the crown [Figure 3a-c].

On the labial side, there was tensile stress concentrated mainly at the cervix, gradually decreasing toward the apical third where compressive stresses were seen. On the lingual side, compressive stress was concentrated at the cervix which decreased gradually till the apical third, where tensile stresses were found appearing.

This indicated that the initial tooth movement was lingual crown tipping of the tooth. The displacement chart also did not show any intrusive movement of the tooth.

Hence, keeping the Fx and Fz constant, the Fy (intrusive forces) were increased from a range of 0.6N to 4.2N till bodily tooth movement was obtained.

| Table 1: Mechanical properties of the different structures |
|----------------------------------|
| Materials | Young’s modulus (N/mm\(^2\)) | Poisson’s ratio |
|-----------|-----------------------------|----------------|
| Tooth     | 1.96×10\(^4\)              | 0.30           |
| Periodontal ligament              | 0.667                       | 0.45           |
| Cortical bone                      | 1.37×10\(^4\)              | 0.26           |
| Cancellous bone                    | 1.37×10\(^3\)              | 0.30           |
At $F_y = 3.6N$, we got stress patterns in PDL which indicated translation and that too in the apical direction [Figure 4a-e].

**DISCUSSION**

The distribution of the stress-strain on the PDL gives an indication of the nature of tooth movement. *In vivo* measurement of stress is difficult at best, and thus the development of an effective model for this purpose was necessary. FEM is a highly precise technique used to analyze structural stress and has been widely used in dental research in the past few years.\(^6,7\)

There are many clinical and biomechanical differences between the LiO and the LaO techniques. These can be attributed to many factors such as difference in the position of brackets, reduced arch perimeter, and variations in the lingual anatomy. These differences between the two techniques do influence the movement of the teeth.

In this study, we created a model of maxillary incisors which was inclined ideally, i.e., at $25^\circ$ to the palatal plane. Maxillary incisors were chosen because they undergo the most detailed tooth movement and are at the highest risk for root resorption.\(^8\)

With data obtained from previous studies and our preexperiments, we started with the application of forces to simulate the force systems in LaO and analyzed the biomechanical effects.

The distribution of stress-strain in the PDL from the cervical margin to the apex showed that the initial tooth movement was almost translation (horizontal), and the center of rotation was located at infinity.

Then, the same loads of $Fx + Fy + Fz$ were applied to simulate the force systems in the LiO and the biomechanical effects were analyzed.

The distribution of stress-strain in the PDL showed that the initial tooth movement was an uncontrolled tipping of the tooth (with lingual crown and labial apex movement).

Vertical difference in the point of force application was suggested as one of the main reason.\(^9\)

In this study, the heights of the application points in LiO and LaO were about 0.7 mm different. Therefore, any horizontal...
force would produce an exaggerated loss of torque in LiO. Since increasing the vertical intrusive forces are seen as a method to reduce the uncontrolled tipping, we increased the vertical intrusive force keeping the Fx and Fz constant.

The aim was to find the Fy value at which the results were similar to those in LaO, i.e., bodily tooth movement in the direction of retraction.

At 3.6N of intrusive force, the distribution of the stress, strain, and displacement in the PDL suggested that bodily tooth movement was obtained. The displacement chart confirmed near translation tooth movement. However, the direction of tooth movement was not in the direction of retraction as was expected.

The reason was explained by Liang et al. who said that biomechanically the intrusive force Fy generated two orthodontic effects: Intrusion of the maxillary incisor and an effect equal to lingual root torque.\[1\]

Since moment = force × distance, the moment generated by the intrusive force in LiO is much weaker, as the distance between the point of force application to the C_res in LiO is significantly shorter than in LaO.\[10,11\]

Hence, such intrusive forces fail to counteract the tendency of lingual crown tipping and to provide adequate torque control for bodily retraction. Therefore, increasing the vertical intrusive forces alone to achieve bodily retraction should be avoided. Moreover, the force is too heavy to be applied in a clinical orthodontic practice. Such high forces can have deleterious effects on the roots.\[8\]

Moreover, in the continuation of the same experiment when we reduced the retraction force Fx, keeping the Fz = 7 N/mm and Fy = 0.65N constant. We found that bodily tooth movement was obtained when the Fx = 0.3N. This indicated that the retraction forces in LiO should be one-third of that used in LaO. Using retraction forces as low as 0.3N may also not be practical for many reasons.

**CONCLUSION**

In a normally inclined tooth, application of loads that produces translation in LaO produces uncontrolled tipping in LiO. Application of higher intrusive forces alone cannot compensate for the biomechanical differences in the two techniques during retraction mechanics. To obtain adequate torque control in LiO, a combination of a significant reduction in horizontal retraction forces, increased labial torque application, and increase in vertical intrusive forces is required.

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**Conflicts of interest**

There are no conflicts of interest.

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