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Original Article

Comparison between Lingual and Labial Orthodontics Based on Treatment of Overbite by Using Rocking Chair Arch wire - A Biomechanical Study

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Abstract

Background Lingual orthodontics (LiO) has developed rapidly in recent years and research on treatment of overbite by using Rocking Chair Arch (RCA) wire of different curve depths is still limited, especially with 3-dimensional Finite Element (FE) models. The main objectives are to study the biomechanical differences in maxillary anterior teeth between lingual and labial orthodontics and observe the lingual mechanics on different inclinations of teeth. **Methods** The force produced by Nickel-Titanium, Stainless Steel (SS) RCA for both sides was measured using Electromechanical Universal Testing Machine. 6 FE models were constructed and divided into 2 groups according to SS wire of 0.016x0.022-inch standard and mushroom arch shaped RCA of curve depth 2, 4, 6 mm. Additional 9 FE models were constructed and divided into 3 groups based on Retroclination (-5°, -10°) and Proclination (+10°). **Results** Use of same diameter of SS RCA with same curve depth but on different sides shows more stress and strain, displacement of teeth in lingual mechanics. Also, stress-strain, displacement increased with increasing RCA curve depth. In LiO, intrusion of normally inclined or proclined teeth are accompanied by little or no labial tipping whereas that of retroclined teeth is accompanied by further lingual tipping. **Conclusion** In the intrusion using Lingual RCA, to avoid the traumatic force to teeth, the curve depth should be lesser than Labial RCA or apply more elastic arch material; Aligning different inclined teeth into normal inclination firstly and proceed with the application of intrusive force can be the best approach.

Keywords

Lingual Orthodontics, Rocking Chair arch wire, Finite Element Method, stress

Introduction

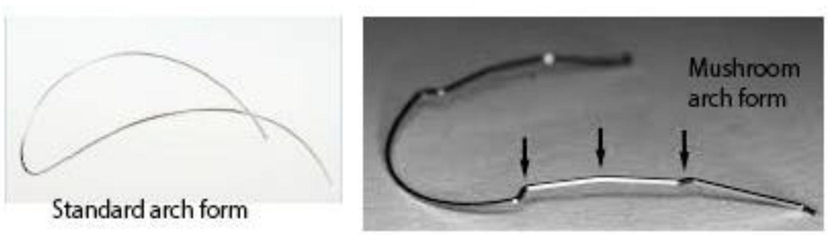
A deep overbite is a common and complex orthodontic problem of many malocclusions[1]. Development of deepening of the bite are mainly contributed by different factors which include the decrease in the upper and lower anterior teeth axial inclinations, vertical skeletal growth and anterior and posterior teeth positions, loss of periodontal support[1]. Due to the potential deleterious effects on the temporomandibular joint, periodontal health and facial aesthetics, correction of a deep overbite is considered as an important part of orthodontic treatment[1]. Overbite correction during orthodontic treatment is often tricky and relapse may occur in some cases[2]. The action of the orthodontic appliance in overbite correction is based on the incisor (Maxillary/or mandibular) intrusion and/or molar extrusion[2, 3]. Two major orthodontic intrusion techniques for maxillary anterior dentition has been developed: the segmented arch and bioprogressive[4]. Currently, a few clinical trials have evaluated variables such as force magnitude, side- effects and application point of the intrusive force for the bio progressive or the segmented arch techniques[4].

Additionally, the reverse curve of Spee NITI arch wire was introduced as an alternative method of incisor intrusion[4]. Another name used for the Reverse curve of Spee arch is the "M" arch, which is named after Dr. Margolias of Boston University and also commonly known as Rocking chair arch wire (RCA-Figure1)[5]. This RCA is curved in a direction opposite to that of the curve of Spee and when these archwires are inserted into the molar tubes, the anterior segment of RCA curves gingivally. And when this anterior segment of arch wires is forced occlusally into the bracket slot it results in an intrusive force on the incisors[6, 7]. Nonetheless, there is a lack of evidence on the quantitative assessment of forces and moments of intrusion systems, especially the effect of reverse curve arch wires on anterior segment of the Maxillary dental arch[4].

Theoretical and experimental biomechanical analyses explain most labial orthodontics (LaO), however the biomechanical principles of lingual orthodontics (LiO) are rarely introduced[8]. Therefore, some guidelines are needed when applying these principles to the lingual technique. LiO is known for its efficient ability to open the bite and to correct overbite[2]. LiO is a more esthetic orthodontic technique than labial orthodontics which has developed rapidly in recent years[9, 10]. Recent improvements in terms of indirect lingual bracket bonding, new advances in arch wire materials and computerized advanced planning systems has made the lingual technique even simpler and more precise[11].

Very few studies have focused on the components of overbite correction in orthodontics and particularly in lingual orthodontics[2]. Therefore for better orthodontic results, it is essential to completely understand the biomechanical differences between lingual and labial orthodontics in maxillary incisors during the intrusion process. The purpose of this study is to a) identify and compare the favorable force for intrusion into anterior teeth both lingual and labial sides of Finite Element (FE) method; b) investigate the effect of intrusive force on different inclination of teeth; emphasizing and analyzing the effective method for bite opening by lingual mechanics and to provide scientific basis for clinical treatment and guidance.

Figure 1 Rocking chair arch wire (RCA) used in labial and lingual side [3]



Methodology

a) Mechanical Testing of Arch wire

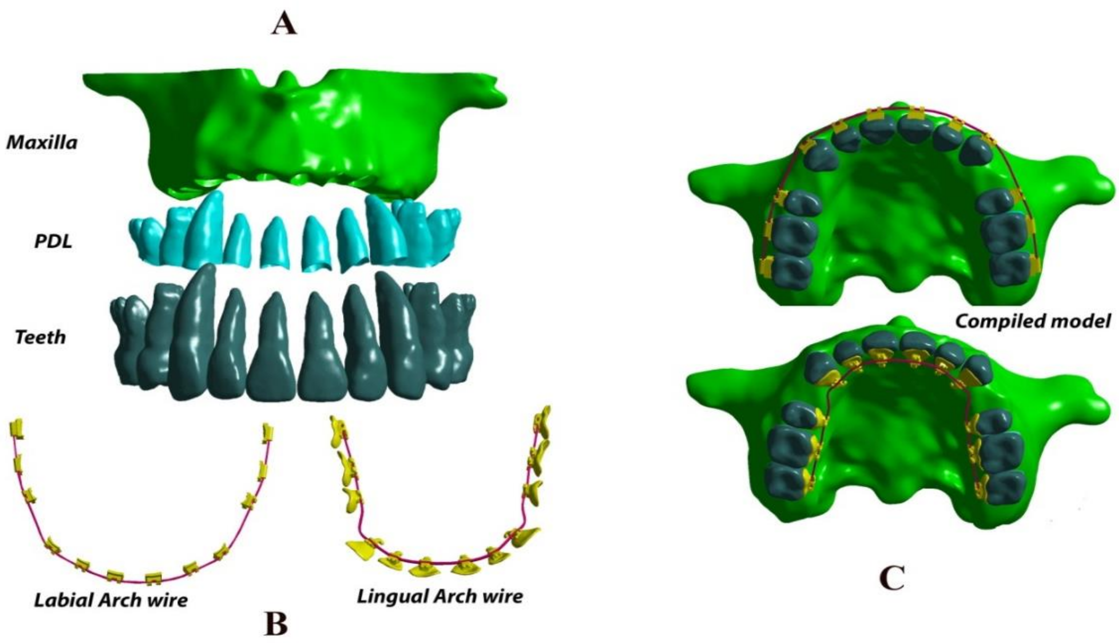
Nickel-Titanium (NITI) and Stainless Steel (SS) arch wire of Standard and Mushroom arch form was collected (Dentaurum). Size of wires were 0.016 inch NITI (labial, lingual), SS (labial, lingual); 0.016x0.022 inch NITI (labial, lingual) SS (labial, lingual) which had Rocking chair arch form of various curve depth i.e. 2,4,6mm. The forces produced were measured using Electromechanical Universal Testing Machine (Model No: C43.104, MTS Systems Corporation, Eden Prairie, USA.

A Universal testing machine measures the force generated when the rocking chair arch wires were compressed beyond their given depth. The main parameter i.e. Maximum force for intrusion of teeth was measured11. The testing machine components Cross-head was programmed to cycle once, at slow speed (0.5mm/min) until the wire were compressed and we repeated it thrice and recorded data. The mean averages were obtained as result. The data were recorded on a computer by using MTS Test Suite program. The outputs were compiled as Excel files. Values were recorded 0.01 mm and 0.01 N (1 N = 100 g).

b) Finite Element (FE) method A CBCT scan projection of an adult maxilla was obtained from the Department of Oral and Maxillofacial Radiology. The Finite Element (FE) model of the maxilla was constructed using Computed Tomography (CT) scans of an adolescent patient. The CT images consisted of 312 transversal sections with a slice thickness of 0.5mm and a pixel width of 0.398 mm. The software MIMICS (Materialise, Leuren, Belgium) and Geomagic Studio (Geomagic Company, NC, and USA) were used to convert CT scanned images into a geometric model of maxilla. The model included 12 teeth, an open space to correspond to the missing first premolar. The compact bone was modeled to have a average thickness of 2.0 mm, similarly trabecular bone with the average thickness of 2 mm and PDL with the average thickness of 0.2 mm using Rapid Form Software (version 6.5; INUS, Seoul, Korea).

A commercial CAD software Solid-Works (Solid-Works Corp., Dassault Systemes Concord, MA, USA) was used to build the orthodontic bracket both for lingual and labial, which was made of SS. The labial and lingual RCA of curve depth 2 mm, 4 mm, 6 mm were constructed and placed on the bracket in their positions. To generate the Geometric model, we assembled cortical bone, trabecular bone, PDL, teeth, brackets and wires as shown in Figure 2.

Figure 2: Geometric model of human maxilla showing A- Bone, PDL, and Teeth; B-Labial and arch wires, C-compiled maxillary arch model.



Then the constructed model was exported to the FE software ANSYS 12.0 (Swanson Analysis Co., Houston, TX, USA). The elements and nodes in the FE model (bone, tooth, PDL, bracket, wire) are listed in Table I.

Table I: Element Assignments in the Finite Element Model

MATERIALS	ELEMENTS	NODES
Cortical Bone	21702	39642
Trabecular Bone	19210	34175
PDL	31180	63382
Teeth	10227	19470
Bracket	60274	109985
Wire	50	608

Part 1- 6 FE models were constructed and divided it into 2 groups. The 2 groups each contained 3 models which were divided according to Stainless Steel wire of 0.016x0.022 inch standard and mushroom arch shaped RCA of curve depth 2, 4, 6 mm.

Part 2- The 9 FE models were constructed and divided into 3 groups based on the Inclination of the teeth. First groups FE models had Proclination (5°) of teeth; Second groups FE models had Retroclination (-5°) of teeth; and Third group had Retroclination (-10°) of teeth. All these groups contained each 3 FE model which were divided according Stainless steel (SS) wire of 0.016x0.022-inch mushroom arch shaped RCA of curve depth 2, 4, 6 mm.

In this study, the materials used were assumed to be linearly elastic, homogenous and isotropic. Here, force was applied to all the FE models, which was obtained by measuring from Electromechanical Universal Testing Machine (Table II).

Results

The force produced by all wires of Standard and Mushroom shaped RCA was measured using Electromechanical Universal Testing Machine and the obtained data is shown in Table-II.

TABLE II

Recordings of Force produced by arch wires (using Electromechanical Testing Machine)

TYPE OF WIRE	DIAMETER OF WIRE (in inch)	CURVE DEPTH (mm)		
		2	4	6
NITI – LABIAL SIDE (STANDARD ARCH FORM)	0.016	0.091	0.105	0.132
	0.016X0.022	0.194	0.2535	0.3175
STAINLESS STEEL – LABIAL SIDE (STANDARD ARCH FORM)	0.016	0.233	0.32	0.362
	0.016X0.022	0.5255	0.831	0.9435
NITI – LINGUAL SIDE (MUSHROOM ARCH FORM)	0.016	0.1275	0.181	0.2825
	0.016X0.022	0.348	0.4455	0.536
STAINLESS STEEL – LINGUAL SIDE (MUSHROOM ARCH FORM)	0.016	0.3535	0.489	0.682
	0.016X0.022	1.389	1.793	1.86

Analyzing Table-II, it shows that the force produced by lingual RCA (NITI/SS) is stronger than the labial RCA and NITI lingual RCA produces low constant forces than SS lingual RCA.

Part 1

Stress Distribution

Figure 3 shows the Von- Mises stress distribution between SS labial/lingual sides of (A-teeth, B-PDL, and C- Bone).

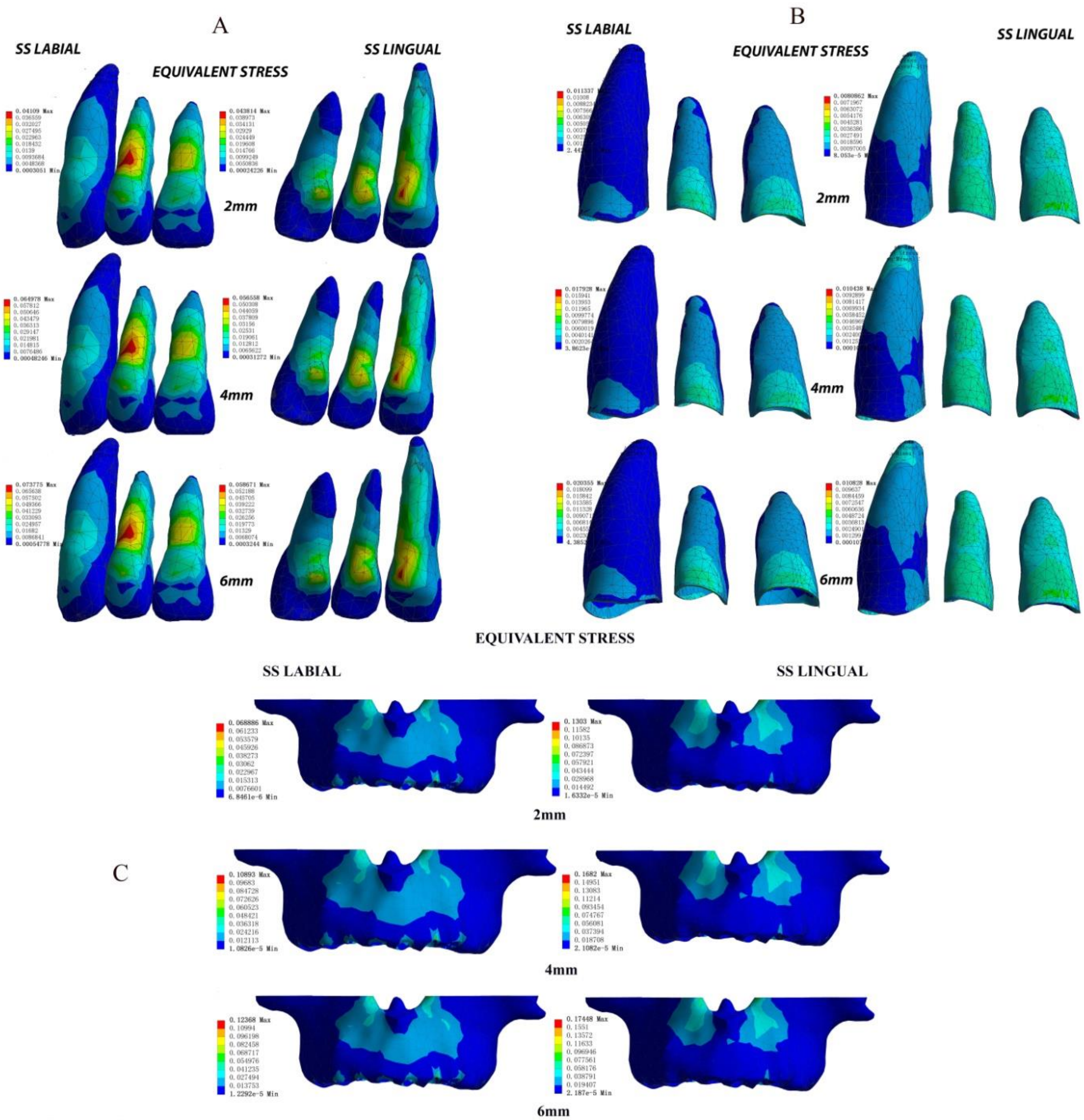


FIGURE 3

Comparing Von- Mises stress distribution between SS labial/ lingual sides of (A- Teeth, B- PDL and C- Bone),

Figure 3A showed more stress produced by SS lingual wires when compared to labial wires and also the RCA of curve depth 6mm showed more stress which decreased by 4mm and 2mm; In figure 3B, SS labial RCA produces more stress in 12 11 21 22 and 23 (FDI Dental Numbering System) and slightly less in 13; In figure 3C, stress was produced more by SS labial RCA in 11 21 22 and lingual RCA in 13 12 23.

Strain Distribution

Figure 4 shows the Equivalent strain distribution between SS labial/lingual sides of (A-teeth, B-PDL, and C- Bone).

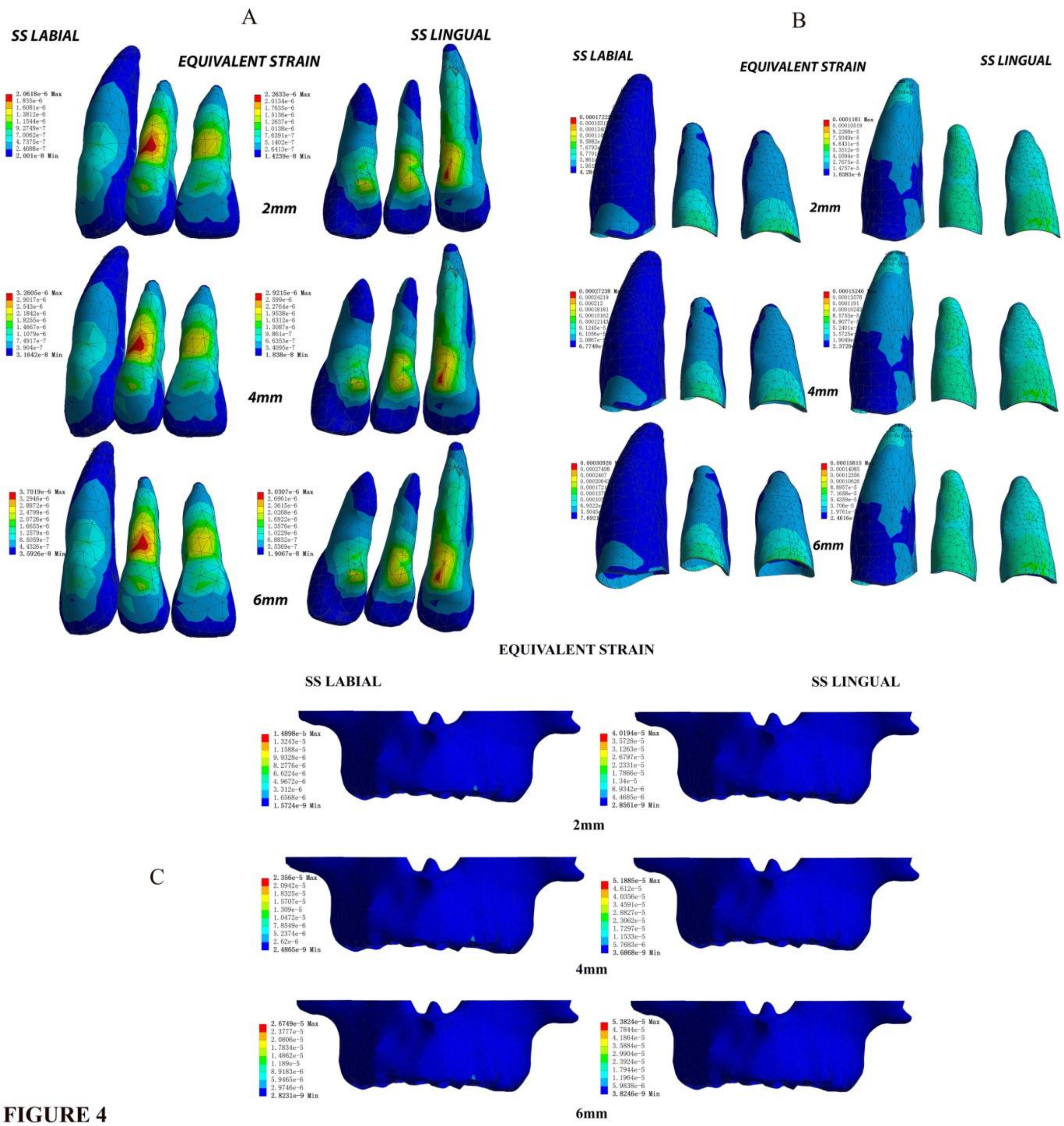


FIGURE 4

Comparing Equivalent strain distribution between SS labial/lingual side of (A- Teeth, B-PDLand C- Bone)

Figure 4A shows more strain produced by SS lingual wires; Figure 4B showed more strain produced by SS labial wires; Figure 4C shows more strain produced by SS labial wire in 11 21 22 and SS lingual in 13 12 23.

Tooth Displacement

Initial displacement of the teeth was calculated at the crown and root tips on Y and Z axis.

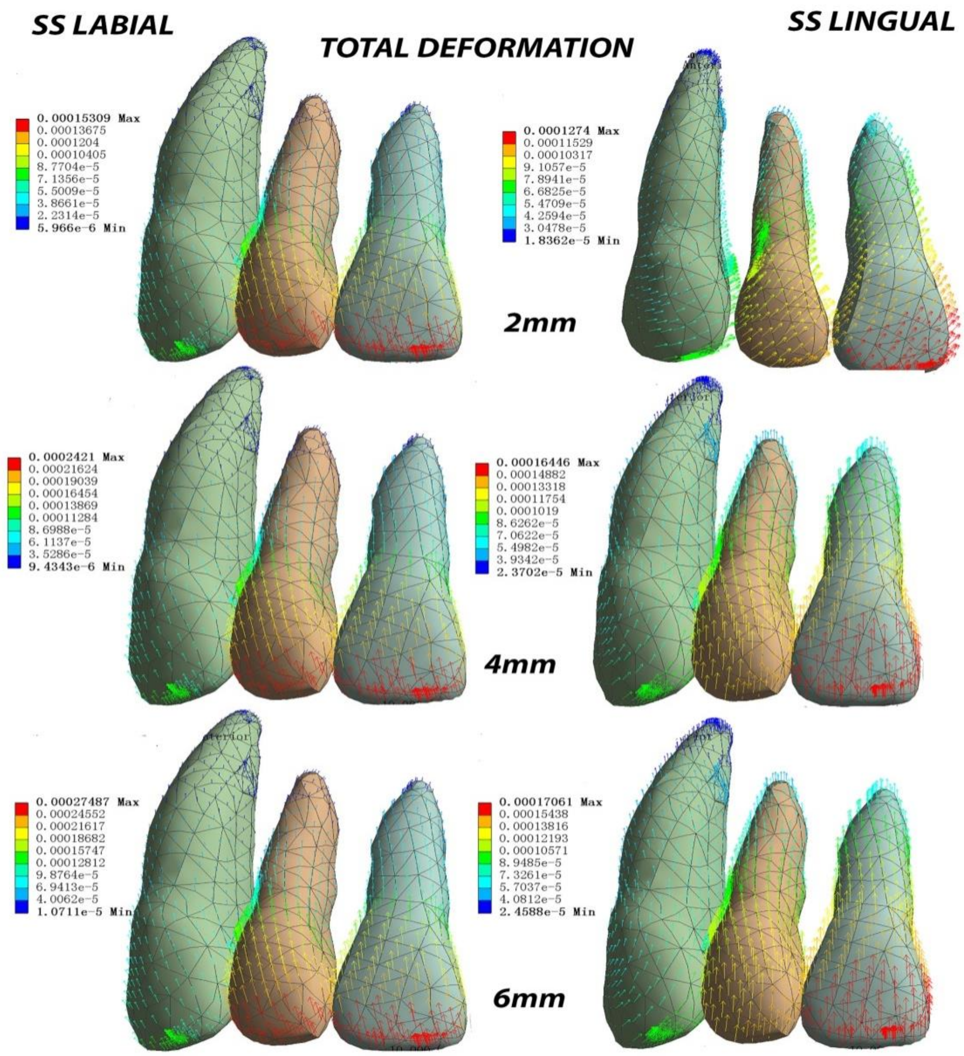


Figure 5

Comparing Total deformation of maxillary anterior teeth between SS labial and lingual sides

Figure 5 shows the tooth displacement of maxillary anterior teeth between SS labial and lingual wires. It shows vertical movement of teeth (i.e. intrusion) was shown more by lingual RCA when compared to labial RCA

Part 2

Displacement

Figure 6 (A,B,C) shows the comparison between different inclinations on the basis of vertical displacement of teeth by using the SS lingual RCA of curve depth 2,4,6, mm respectively.

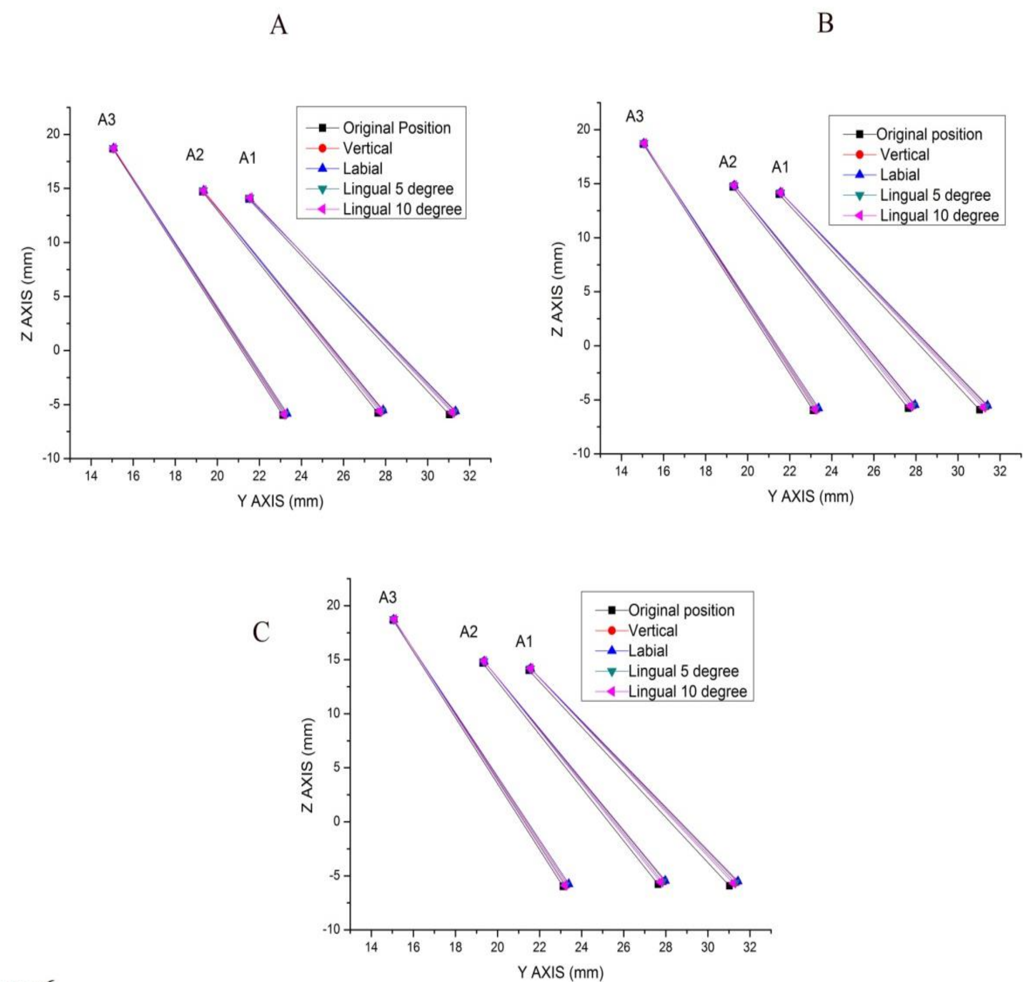


Figure 6

Comparison between different inclinations of right maxillary anterior teeth on the basis of Vertical displacement of teeth.

Firstly, the original positions were identified and then the displacements produced by different inclinations are visualized. Normal inclination doesn't show any tipping and vertical displacement is less. Labial inclination teeth were displaced slightly labial (labial tipping) and vertical displacement were too less (Figure 6A) and increased labial tipping in the tooth where RCA of curve depth was 4, 6 mm. (Figure 6B, C). Lingual inclination both 5 degree and 10 degree teeth showed lingual tipping i.e. tooth displaced more lingual and vertical displacement were less.

Discussion

Esthetics is considered as a most significant issue in orthodontic treatment particularly for adult patients and it is incumbent on orthodontists to be aware of the importance to fulfill the patients concerns and expectations[8]. So, lingual appliance can be a viable option for the patient's seeking orthodontic treatment. It is well tolerated appliance. But due to poor accessibility, variations in anatomy of lingual surfaces, need of a laboratory and complicated mechanics, increase duration and cost, needs a much different consideration as compared to LaO. The disadvantages of lingual orthodontics include the excessive treatment time, complicated biomechanics, discomfort to the patient, expensive lab procedures and material, speech problem and tongue soreness[13]. One of the major challenges faced by the orthodontists is to understand and predict the complexities involved in the response to the teeth to the forces and the moments[13]. To study the relationship between different force systems and distribution of stress/strain on tooth and its surrounding tissues, many methods have been used which are Finite element methods (FE), Laser holographic techniques, photo elastic studies and mathematical studies representing the in vivo situation. All of these techniques have inherent advantages and disadvantages[14]. FE method was chosen for the current study.

FE method or FE analysis is a contemporary research tool for an orthodontist[15], which was introduced as one of the numerical analyses. It has also become a useful technique for stress and strain analysis in biological systems. The method consists of a graphic computer simulation of different objects that are divided by a process known as "discretization" into small segments called "elements". The "elements" are numbered in a finite number of point called "nodes"[16,14]. Simulation of tooth movement and optimization of orthodontic mechanics is proved to be effective in FE method[9]. However, no studies have compared intrusive movement between lingual and labial orthodontics with FE method. Analytical application of various force systems at any point, any direction and quantitative assessment of the distribution of such forces through the wire and related structures is possible in FE method[14]. It also provides the freedom to simulate orthodontic force applied clinically and help to analyze the response of the dentition to the force in 3D space[14].

In this study, force measured by Electromechanical testing machine showed the differences between lingual and labial are mainly due to the factors (size, material, form of the wire). Even though the arch wire in lingual are with the same parameter as the labial wire, but the length of the wire in lingual is shorter which may cause less flexibility of wire and ultimately result in larger force production. The phenomenon we observed above, suggested us to do the FE method analysis to investigate the effect on teeth, bone and PDL.

The result of the current study showed that the stress produced by the lingual appliance was always greater than that generated by labial appliance. This was undoubtedly due to the smaller inter-bracket distance in the anterior sector, which results in a greater load on the teeth[11]. To understand the reasons we should focus on biomechanics of LiO i.e. the relationship between the Point of Force (PF) and the Center of resistance (C_{res}) is different from LiO and LaO because of the different position of the brackets[16]. (See Figure 7A) Because the distance (D) between C_{res} and PF is smaller in LiO than in LaO, the moments of forces in LiO are smaller (moment = force x distance)[11, 17].

The biomechanical response to maxillary incisors was compared with labial and lingual force applications with a three-dimensional FE method which showed that apically directed vertical forces applied at the lingual points produced more uniform tooth displacements and stress distributions. It was concluded that more optimal tooth movement in terms of intrusion and subsequent stress distribution in the periodontal ligament was obtained by lingual force application[17].

The PDL has a major role in orthodontic tooth movement because its thickness and viscoelasticity vary along the root surfaces[16].

During the orthodontic tooth movement, these variations may have an influence over the intensity of the biologic events that takes place clinically[16]. According to the tooth movement mechanics, different force application points will result in difference in stress- strain because PDL is not totally a rigid material but a elastic material[9]. The distribution of stress- strain in LiO was approximately 15% lower than LaO when only moments were applied in LiO and LaO during repeated tests. In this study, PDL produced more stress while using labial appliance because the study objects was elastic material.

Since the stress and strain are larger in lingual wire than in labial wire, we should emphasize on the using RCA of curve depth lesser to the depth used on labial side. If the same curve depth is used as in labial it may result in harmful effects on teeth i.e. root resorption, Bone i.e. Alveolar bone defects, PDL – maximum stress concentration result in PDL injury and the PDL reconstruction phenomenon occurs slowly.

Current studies to illustrate that vertical forces in LiO may produce much more complicated and unpredictable tooth movement because these vertical forces affect the teeth differently with change in tooth inclination and also much more sensitive to the bracket position than that in LaO[13]. (Figure 7B) show the distance in the vertical plane between a lingual bracket and the C_{res} is greater than between a labial bracket and $C_{res.}$ In LaO, the net force will generally be ahead of the C_{res}, whereas in LiO, it will be behind the C_{res} as shown in Figure 7B[8]. Due to this LiO biomechanics, the result showed intrusion of normally inclined or proclined teeth is accompanied by little or no labial tipping due to force vector passing through or closer to centre of resistance (C_{res}) whereas that of retroclined teeth are accompanied by further lingual tipping due to force vector passing lingual to the centre of resistance[13]. The clinical implication of this geometry indicated that the tendency for retroclination of anterior teeth is more pronounced in LiO which can be counteracted by creating a negative buccal force by incorporating a degree of labial crown torque(palatal root torque)[8]. It is more reasonable to perform intrusion when the tooth is at its normal inclination to the occlusal plane because the maximum Von Mises stress at root apex was least in case of normal inclined tooth[18].

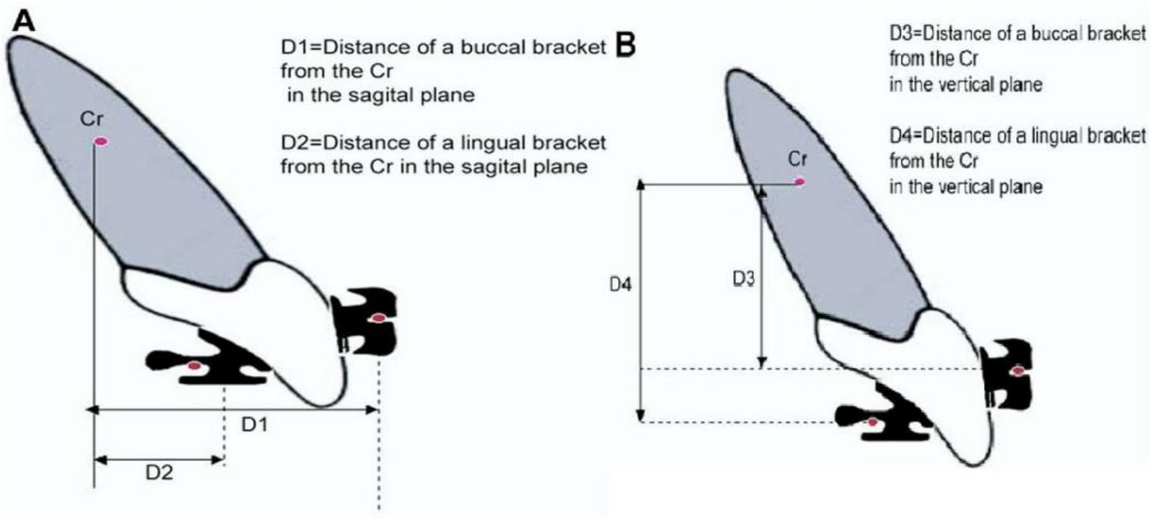


Figure 7

(A) Comparison between buccal and lingual brackets in the sagittal plane.The distance of alingual bracket from the center of resistance (Cr) of the anterior tooth is shorter than the distance ofbuccal bracket from the Cr.[8]

(B) Comparison between buccal and lingual brackets in the vertical plane.Thedistance of a lingual bracket from the center of resistance(Cr) of the anterior tooth is longer than thedistance of buccal bracket from the Cr [8]

Conclusion

The knowledge of LiO biomechanics where it differs from LaO is essential. Treatment with LiO can be as successful and satisfying as LaO[19]. The biomechanical difference of Stress, strain, displacement of the maxillary anterior teeth between LiO and LaO was significant. Both lingual and labial mechanics provoke different stress patterns and consequently tooth movements[12]. The data onto our study may provide a valuable reference to future clinical studies concluding that:

- The vertical movement of tooth (intrusion) can be well obtained by using Lingual RCA but limiting the curve depth lesser than labial RCA to minimize the traumatic force to the teeth or use more elastic material for e.g. NITI or β- Ti (Beta- Titanium).
- Using the Lingual RCA for intrusion on different inclination can produce undesired tooth movement. Considering and aligning teeth into normal inclination and proceeding with the application of force to obtain vertical movement can be the best approach.

Conflict of Interest

None

Acknowledgement

None

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