ORIGINAL ARTICLE

COMPARISON OF STRESS DISTRIBUTION IN ANTERIOR SEGMENT WITH SECOND PREMOLAR EXTRACTION– A FINITE ELEMENT STUDY

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ABSTRACT :

Background: Aim of this research was to compare the stress distribution in anterior segment with class I elastics and class II elastics with second premolar extraction. Beegs mechanics was used for this research.

Material & Method: CBCT of 20 years old male patient was used for this research. Further with the help computer geometric model of both maxillary and mandibular arch it was converted to finite element method. Every individual tooth, bone, brackets, arch wire, elastics, buccal tube and periodontal ligament were transformed into nodes and elements. Then calculation was processed.

Result: With the use of class I elastics maximum movement was noticed in central incisors. In the posterior segment first molar moved distally by 0.001mm. with the use of class II elastics maximum movement was noticed in central incisors. In the posterior segment first molar showed distal movement by0.004mm. Whereas second premolar too showed distally movement by movement 0.003 mm.

INTRODUCTION :

Orthodontics tends to deal with not only diagnosis and prevention of developing malocclusion but also in treating developing or developed malocclusion. Being an orthodontist we in our daily practice decide the treatment plan for the patients. Myofunctional appliance is option in growing patients. In non-growing patient we chose the option of fixed orthodontic treatment, it could be either extraction or non extraction.[1] In order to make best treatment plan for the patient there is necessity to gingerly perform the cephalometric analysis, model analysis and photographic analysis. The decision is also related to an entity called "clinical judgement". This judgement is derived from experience with similar, extensive training and a rather subjective integration of the patient's orthodontic situation with aforementioned diagnostic evidence.[2] First premolars are extracted in maximum anchorage situations and second premolars are usually extracted in borderline cases3. These choices are based on William's Hypothesis in 1969[4] which is stated that by a choice in the location of the extraction site, there would be a change in the root surface areas between the anterior and posterior segments, enough to influence the potential for incisor retraction. According to Steyn et al[5] whether four first premolars or four second premolars are extracted, the soft tissue appearance of the patient after orthodontic treatment will virtually be the same. Clinically, it is easier to extract second premolars since the anatomy of maxillary first premolars makes it more liable to fracture. Maxillary first premolar has neck, variable furcation and they have thin roots. second premolar anatomy is less variable. Therefore, their liability to fracture is less[6]. Accordingly in orthodontic process, it is essential to examine the stress distribution on teeth in both the extraction cases i.e., first premolar and second premolar extraction as well as requirement of torque after first premolar and second premolar extraction. Hocevar used hypothesis for the treatment of orthodontic patient, a short of "artist's conception" of the working force systems, intended to illustrate and explain in a simplistic

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fashion the manner in which force applied in orthodontic treatment bring about specific predictable tooth movements.

If the treatment of choice is extraction of all first premolars then our concern will further shift on to the method of space closure. We have multiple of option space closure using class I[7], class II[8], class III[9], Niti coil spring[10], implant[11,12,13] etc...

So, the aim of present research was comparison of stress distribution in anterior segment with class I elastics and class II elastics with first premolar extraction through Beggs mechanotherapy.[14,15,16]

There was two ways of conducting the research. First choice would have been doing cephalometric comparison and second choice was to proceed the study through finite element method(FEM). It is difficult to make clinical experimental models that account for the effect of one variable to the exclusion of other variable because many variable interact to produce various biomechanical behaviour of a tooth in a real time clinical situation.

We decided to conduct our research through FEM method. Finite element method (FEM) has been used extensively in the field of automobiles, aeronautics and mechanical engineering where it allows testing of various machines under the simulated environment in the computer. Stress generated in various part of these machines (internal and external) can be effectively charted out and thereby necessary steps can be undertaken for their structural modification accordingly. The FEM, borrowed from discipline of engineering, is a fairly well known research adjunct in orthodontics and offers an advantage that the biological system can be modelled in the computer environment and exclusively effects of various parameters can be assessed without interference from other variables. Therefore, the FEM is a reasonable for elucidating the biomechanical effects occurring on tooth movement.

MATERIALS AND METHOD :

In the present research, 2 three dimensional finite element models of maxilla and mandible were generated, both the models had second premolar extraction consisting of remaining 12 teeth with its periodontal ligament, alveolar bone, brackets, arch-wire, class I and class II elastics. Aim of the present research was comparison of stress distribution in anterior segment with class I and class II elastics. Mechanotherapy used as fixed orthodontic treatment was Beggs mechanotherapy. Nodes and element used in this research is shown in table 1.

	Teeth	Nodes	Element
MAXILLA	Central incisor	1458	4762
	Lateral incisor	1098	3478
	Canine	1316	4176
	First premolar	1848	6352
	Second premolar	1426	4792
	First molar	2240	7650
	Second molar	2048	6786
	Periodontal ligament	4040	7721
	Bone	46303	220561
MANDIBLE	Central incisor	1188	3750
	Lateral incisor	1330	4242
	Canine	1844	6098
	First premolar	1522	4966
	Second premolar	1746	5814
	First molar	2574	8874
	Second molar	2446	8360
	Periodontal ligament	5624	10822
	Bone	54149	247203
	Bracket	16709	47384
	Arch wire/ buccal tube	4195	226
	Total	89641	392583

Table 1:Total nodes and element used

In the second premolar extraction case, where class I& class II elastics were used total nodes and element were:-

Nodes= 93082

Elements= 42459

In this study 2 models were formed-

1. In the first constructed model, maxillary second premolars was extracted and class I elastic was placed and force of 50grams was applied at the time of retraction was applied in both the models (fig 1).
2. In the second constructed model, maxillary second premolars was extracted and class II elastic was place. In this study, the geometric

system was coordinated.

X denotes -Lateral direction

Y denotes anterio-posterior Direction

Z denotes along axis of the teeth or Vertical direction positive Z means Intrusion, and negative Z means extrusion.

In all the four models, 50gms force was applied. Cuspid circle was placed 3mm mesial to canine. Anchor bend of 350 was given 3mm mesial to the molar tube.

RESULTS :

MODEL 1

In this model second premolar extraction was done and class I elastics were placed, 50gms force was generated. When force was applied, it was noted that in anterior segment i.e., central incisors, lateral incisors, canines & first premolar moved distally by 0.040mm, 0.018mm, 0.023mm& 0.006mm respectively (table 2). Maximum movement was noticed in central incisors 0.040mm. In the posterior segment first molar moved distally by 0.001mm. Von-mises stress in hard bone was confined to the central incisors and lateral incisor and also at the distal side of the canine area where maximum tooth movement was seen. It was about 2.947 MPa.

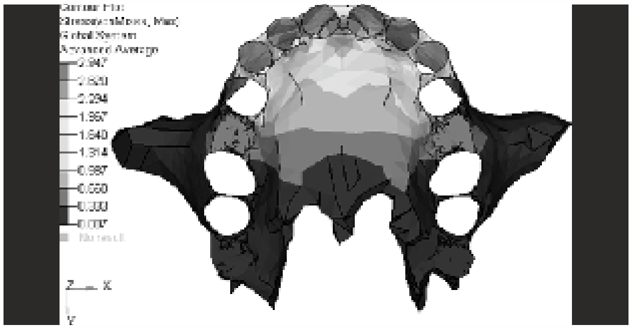

Fig 1-von- mises stress in hard bone in second premolar extraction with class I elastics (occlusal view)

Maximum von-mises stress in soft bone was seen observed in the buccal side of anterior teeth was around 0.177 MPa. Maximum Von-Mises Stress in PDL observed on first premolar PDL on the distal side and is around 0.003 MPa.Total gap Closure with Class-I elastic on day1 was 0.005mm. First premolar movement (distal) = 0.006 mm First molar also moved mesially by 0.001mm So total gap closure = 0.006-0.001 = 0.005 mm.

Tooth	X-AXIS (Transverse plane)	Y- AXIS (Sagittal plane)	Z- AXIS (Vertical plane)
Central incisors	0.004 mm	0.040 mm	0.040 mm
Lateral incisors	0.003 mm	0.018 mm	0.032 mm
Canine	0.008 mm	0.023 mm	0.016 mm
First premolar	0.003 mm	0.006 mm	0.003 mm
First molar	0.002 mm	0.001 mm	-0.001mm

Table 2:Individual tooth movement in X, Y& Zaxis with second premolar extraction & class I elastics. Force applied-50gms & D scale 10

Movement of every individual tooth is shown in table-4.The movement is represented in all the three plane of space i.e., X,Y& Z axis with class I elastic

MODEL 2

In the second model second premolar extraction was done and class II elastics were placed, 50gms force was generated. When force was applied, it was noted that in anterior segment i.e., central incisors, lateral incisors, canines & first premolar moved distally by 0.047mm, 0.036mm, 0.020mm & 0.008mm respectively (table 3). Maximum movement was noticed in central incisors 0.047mm. In the posterior segment first molar moved distally by 0.003mm.Von-mises stress in hard bone was confined at buccal side of anterior teeth where maximum tooth movement was seen. It was about 3.293MPa. Maximum von-mises stress in soft bone was seen observed at the anterior teeth segment was around. Maximum Von-Mises Stress in PDL observed on the first premolar PDL on the mesial side was0.003 MPa. Total gap Closure with Class-I elastic on day1 was 0.005mm. First premolar movement (distal) = 0.008 mm. First molar also moved mesial by 0.003mm.

So total gap closure = 0.008-0.003 = 0.005 mm.

Max Von-mises stress is observed at Condyle region of hard bone and is around 2.784 Mpa. Max Von-mises stress is observed at Condyle region of Soft bone and is around 0.22 MPa. The movement is represented in all the three plane of space i.e., X,Y& Z axis.

Tooth	X-AXIS (Transverse plane)	Y- AXIS (Sagittal plane)	Z- AXIS (Vertical plane)
Central incisors	0.007mm	0.047 mm	0.045 mm
Lateral incisors	0.005mm	0.036 mm	0.038mm
Canine	0.010mm	0.020 mm	0.021mm
First premolar	0.004mm	0.008 mm	0.004mm
First molar	0.002mm	0.003 mm	-0.002mm

Table 3:Individual tooth movement in X, Y& Zaxis with first premolar extraction & class II elastics. Forces applied- 50gms & D scale 10

Tipping	Central inc isors	Lateral incisors	Canine	First premolar
Model 3	1.2	0.9	0.5	0.3
Model 4	1.6	1.1	0.6	0.7

Table 4:- Tipping angle of both the models

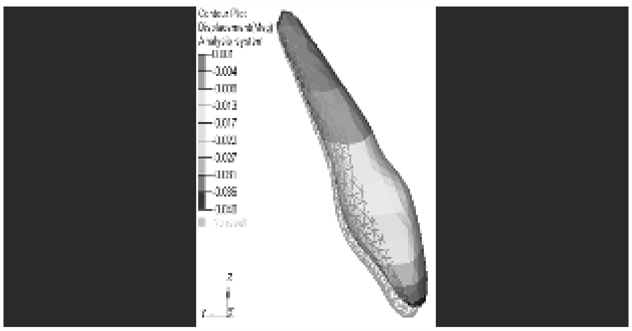

Fig 5:- calculation of tipping angle

DISCUSSION

The spatial relationship between the forces and roots determine how the teeth will move. This research covers the situations in which forces are applied via "single- point" non-rigid contact with teeth through the finite element analysis.

A tridimensional numerical simulation of human maxillary dentition along with maxilla & mandible was generated. and FEM was employed for the analysis of the result.

Hocevar[17] hypothesized an idealized system in which a tooth is thought of as two dimensional body having its mass uniformly distributed throughout its root and lying on a frictionless plane. The tooth's mass may be considered as being concentrated at a single point in the center of the root i.e., the center of mass (CM). Any force applied at the bracket would cause translation of the center of mass along a line parallel to the line of force, the acceleration being proportional to force magnitude. Forces directed along the bracket- CM line would also create a moment resulting in rotation of the tooth about CM. The magnitude of the moment produced and thus the rate of induction of rotation, is directly proportional to the perpendicular distance from the CM to the line of force and to the force magnitude. Thus the force passing close to the centre of resistance would cause very little rotation compared to translation, whereas a force perpendicular to the bracket would yield a much greater degree of rotation relative to translation.

When a moment created by a light force is applied to a tooth, the strain is concentrated in the areas of the alveolar crest and apex and is adequate to induce a biologic response yielding rapid movement of these portions of the root and of the crown. The strain around the middle third of the root is minimal, so that translation of centre of resistance(Cres) is insignificant on a clinically relevant time scale; it is completely outstripped and overshadowed by the tipping. If the moment were decreased by directing the force very close to CRes, then there would be significant translation relative to tipping, but the movement would be very slow because the strain would be relatively evenly distributed throughout the socket area and would be minimal at any particular point. An attempt to increase the absolute rate of translation would require a much greater force to produce sufficient strain throughout the socket area to stimulate enough cellular activity to allow the root to move bodily.

This is a plausible explanation for the clinical impression that teeth can be tipped, but not translated, easily and quickly with light forces, and for the anchorage phenomenon of "differential response to force" employed in the Beggs technique. Light force, just sufficient to produce rapid tipping if applied in such a way as to concentrate strain toward apex and alveolar crest, may cause negligible movement in a clinically relevant time period if delivered so as to spread the strain evenly over a large socket area so that the strain is not sufficient at any point to incite enough osteoclastic activity to allow the tooth to move. Thus can anterior teeth be tipped posteriorly readily by a force whose reaction is too light to protract posterior teeth that are not allowed to tip. Bodily retraction of the anterior teeth would require more force. If a heavy force were employed, unless its moment arm on the anterior teeth were kept very small, it might produce extreme strain at the alveolar crest and apex, perhaps even inhibiting the biologic processes required for tooth movement, necessitating undermining resorption and inducing pathosis. This discussion will be concerned only with light forces.

Hocevar[17] further states that Understanding the principles of moments and couples enables us to gain insight into the amount of force that is available for incisor intrusion by analyzing the interaction of arch wires and elastics at the molars. Arch wires and molar tubes act as levers and fulcra respectively.

Forces are exerted on the dentoalveolar structures in reaction to arch wires delivering 60gms of intrusive force at the midline (that is, 30gms per side). In the maxilla, the 30gms force acting at the end of the lever arm 36 mm from the fulcrum (mesial end of the molar tube) must be balanced by a 180gms force in the same direction at the distal end of the 6 mm long tube (30gms x 36 mm. = 180gms x 6 mm.).

In the M 1 second premolar extraction was done and class I elastics generating force of 50gms were applied and it was noted that in anterior segment i.e., central incisors, lateral incisors, canines & first premolar moved distally by 0.040mm, 0.018mm, 0.023mm & 0.006mm respectively. Maximum movement was noticed in central incisors.

In the M 2 second premolar extraction was done and class II elastics generating force of 50gms were applied. When force was applied, it was noted that in anterior segment i.e., central incisors, lateral incisors, canines & first premolar moved distally by 0.047mm, 0.036mm, 0.020mm & 0.008mm respectively. Maximum movement was noticed in central incisors.

Maximum tipping was noted in central incisors then in lateral incisors and least on canine in both the models. As stated when the force is applied to centre of resistance it will lead to translation. But, forces perpendicular to the bracket centre of resistance line at the bracket would yield a much greater degree of rotation relative to translation. Center of resistance of the anterior segment is between lateral incisors and canine at 1/3 rd of the apex and slightly more close towards the canine. Greater the distance of a tooth from the centre of resistance the greater the tendency of tipping. Hence central incisors tipped more distally.

Tipping of the teeth was observed more in M 2 then in M 1. In the class II elastic cases the resultant vector of force is passing more posteriorly when compared to the class I elastic cases. Hence, tipping of the anterior segment.

Maximum Von-mises stress in M 1 hard bone was confined to the central incisors and lateral incisor. It was about 2.947 MPa. Von-mises stress in soft bone was seen observed the buccal side of anterior teeth was around 0.177MPa. Von-Mises Stress in PDL observed on first premolar PDL on the distal side and is around 0.003MPa.

Maximum Von-mises stress in M 2 hard bone was confined at central incisors& lateral incisors. It was about3.293MPa. Von-mises stress in soft bone was seen observed at the anterior teeth segment was around 0.185MPa. Von-Mises Stress in PDL observed on the first premolar PDL on the mesial side was 0.003 MPa.

Maximum stress was observed in model 2. It is because the amount of tipping is more in model 2 than in model 1. So, more stress was generated on the model 2.

CONCLUSION :

A tridimensional numerical simulation of human maxillary dentition along with maxilla & mandible was generated. FEM was employed for the analysis of the result. Maximum stress was confined to the area where maximum tooth movement was seen. Like in this case maximum stress was observed in central incisors. So, the maximum von mises stress in hard bone, soft bone & PDL was seen around the central incisors. Maximum tipping was noted in central incisors then in lateral incisors and least on canine in both the models. As we know centre of resistance of the anterior segment is between lateral incisors and canine at 1/3 rd of the apex and slightly more close towards the canine .Greater the distance of a tooth from the centre of resistance the greater the tendency of tipping. Hence central incisors tipped more distally.

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