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Original Article

Dentistry Section

Evaluation of Effects and Effectiveness of Various α and β Angulations for Three Different Loop Made of Stainless Steel Arch Wires – A FEM Study

SUPRADEEP KUMAR KAMISETTY[1], RAGHUVEER N[2], RAJAVIKRAM N[3], CHAKRAPANI N[4], DWARAGESH[5], PRAVEN[6]

ABSTRACT

Introduction: Evaluations on retraction loop designs have been limited to describe the force systems applied to the buccal surfaces of the tooth that can be in different planes resulting undesirable effects, needing corrective action in future. By initially understanding these effects, modifications to the loop design can essentially counteract the undesired affects.

Aim: To deter-mine Moments & M/F ratios produced by different gabling in the three retraction loops (Tear drop loop, T-loop, Open vertical loop) and movement of the anterior teeth and posterior teeth) of the maxillary arch in an extraction model, on activation of three retraction loops by1 mm.

Materials and Methods: A PC with Quad core processor, 8GB RAM, 1TB storage space and Graphic Accelerator was used.

Computer Software: ANSYS Version11, PRO/ENGINEER was used in the study. The first step is modeling, done by using Pro/Engineer software and for creating a model the CT scan data is required. The maxilla with teeth of a patient is scanned at various sections at regular intervals of 0.5 mm. These scanned images are then imported into Pro/E software to various offset planes. Once imported, the software can do an automatic meshing and establishes contact automatically.

Results: When angulations increases intrusive or extrusive movements and movements in horizontal direction of crown tip and root tip increases. All values of T-loop are more than Teardrop loop and less than Open vertical loop.

Conclusion: FEM study concludes that Teardrop loop with 10-20(α-β) combination is preferred for Group A anchorage.

Keywords: α-β Angulations, Frictionless mechanics, FEM, M/F Ratio, Open vertical loop, Tear drop loop, T-loop

INTRODUCTION

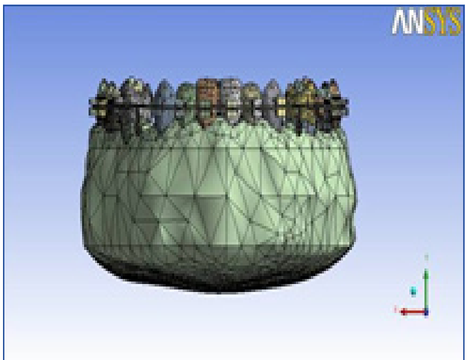
Space closure is a major challenge in orthodontics, as it requires the application of a specific force system. Any quick mechanics used to retract the anteriors to close these spaces has resulted in failure of the attempt and causing more relapse and disastrous occlusion. For the closure of extraction spaces there are two methods i.e. loop mechanics and sliding mechanic of which loop mechanics is preferred over sliding mechanics due to absence of friction. The use of frictionless mechanics for space closure has been advocated by Burstone [1], Faulkner [2] and Germane [3].

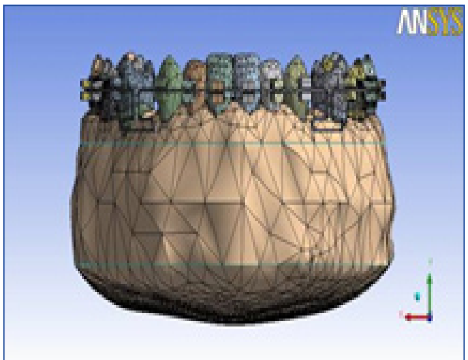
All evaluations on retraction loop designs have been limited to describe the force systems. These force systems are usually applied to the buccal surfaces of the tooth that can be in different planes. They can result in three-dimensional effects that are undesirable and therefore require further corrective action in the future. By initially understanding these effects, they can be minimized and it may also be possible to include modifications to the loop design that can essentially counteract the undesired effects.

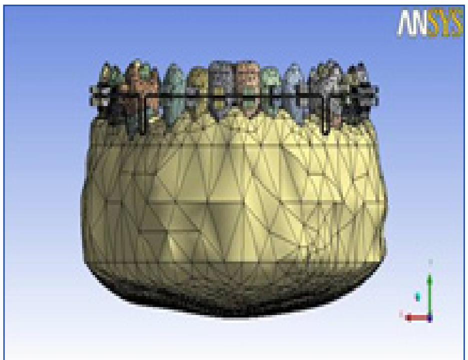
There is a lot of uncertainty regarding the angulations of the gable bends incorporated in the retraction loop to increase the moment and bring about the required type of tooth movement. Studies by Nanda and Burstone highlighted the importance of gabling during retraction but the degree of gabling varied between the authors [4].

Some authors like Gjesing [5] believed in gabling of the legs depending on the anchorage requirements while others like Demetrios and Halazonetis [6] advocated the placement of a total of 400 gabling in both the legs of the retraction loop. According to Faulkner, the optimum preactivation is largely dependent on the wire size, the modulus of elasticity, and the elastic limit of the particular material.

Finite Element Method (FEM), which is an engineering method of calculating stresses and strains in all materials including living







[Table/Fig-1]: Meshed model of maxilla with tear drop loop from front side **[Table/Fig-2]:** Meshed model of maxilla with T loop from front side **[Table/Fig-3]:** Meshed model of maxilla with open vertical loop from front side

α – β angulations	α M/F	β M/F	α momentum	β momentum
			gm-mm	gm-mm
5-10	18.1	26.5	1423.7	2020.7
5-15	14.5	21.9	1598.4	2284.8
5-20	12.4	19.4	1787.1	2410.2
10-15	11.8	17.8	1831.5	2499.2
10-20	10.3	15.3	1909.1	2761.9
10-25	9.1	14.9	2165.4	2821.1
15-20	8.3	10.4	2498.4	2883.6
15-25	7.7	9.8	2575.7	3156.8
15-30	6.4	8.3	2676.3	3343.7

[Table/Fig-4]: Wire 1 - Tear Drop Loop

α – β angulations	α M/F	β M/F	α momentum	β momentum
			gm-mm	gm-mm
5-10	21.3	33.4	1845.3	2427.4
5-15	18.7	27.7	1987.5	2612.9
5-20	16.3	24.3	2045.8	2773.6
10-15	14.8	21.9	2358.9	2812.5
10-20	12.4	19.6	2459.3	3192.9
10-25	11.5	16.3	2583.8	3212.7
15-20	10.4	14.9	2834.9	3299.3
15-25	8.7	12.3	2949.1	3479.3
15-30	7.9	10.3	3068.7	3661.6

[Table/Fig-5]: Wire 2 - Tear-Loop

α – β angulations	α M/F	β M/F	α momentum	β momentum
			gm-mm	gm-mm
5-10	26.1	37.1	2267.1	2781.3
5-15	22.4	33.9	2386.5	2899.9
5-20	18.9	27.4	2479.4	3001.9
10-15	17.5	24.1	2759.7	3095.1
10-20	14.8	21.9	2849.8	3239.7
10-25	12.3	19.5	2952.6	3469.8
15-20	11.6	18.3	3278.4	3681.4
15-25	10.8	14.2	3343.9	3841.8
15-30	9.7	12.5	3482.9	4034.2

[Table/Fig-6]: Wire 3 – Open Vertical Loop

tissues has made it possible to adequately model the tooth and periodontal structure for scientific checking and validating the clinical assumptions. FEM offers an ideal method for accurate modeling of the tooth-periodontium system with its complicated three-dimensional geometry.

The present FEM study was planned to access the effectiveness of Tear drop loop, Open Vertical loop and T-loop and also to analyse the type of tooth movements produced in the anteriors and posteriors during extraction space closure with various alfa and beta angulations

MATERIALS AND METHODS

The study was carried out at Versetia Technologies, Chennai, India in 2011. The requirements for the study were: Computer hardware: A PC with Quad core processor, 8GB RAM, 1TB storage space and Graphic Accelerator was used.

Computer Software: ANSYS Version 11 and PRO/ENGINEER. A three dimensional FEM model of a maxilla with all the teeth except first premolar was created and M/F ratios, moments and movements of anterior and posterior teeth were calculated.

The parameters chosen were three different retraction loops with different alpha and beta angulations to determine the effect on the anterior and posterior teeth. Tooth movement was analysed for displacement of nodes at the crown tip and root tip to determine mesio -distal tipping and intrusion. The wire material and dimension used was 0.019 " x 0.025" stainless steel.

Modelling of Continuous Retraction Loops in This Study

Tear drop loop: The Tear drop loop is made in 0.019" x. 0.025" SS wire and positioned in bracket slot at a distance of 2mm from the center of extraction space towards posterior segment. The lengths of the vertical legs of the loop are 10mm each [Table/Fig-1].

T Loop: The T loop was made in 0.019"x 0.025" SS wire and positioned in bracket slot at a distance of 2mm from the center of extraction space towards posterior segment. The vertical legs of the loop were 8mm each and vertical length of horizontal component is 2mm , making total vertical length of loop as 10mm . The horizontal length of T loop is 10mm and distance between two vertical legs is 2mm [Table/Fig-2].

Open vertical loop: The open vertical loop is made in 0.019" x 0.025" SS wire and positioned in bracket slot at a distance of 2mm from the center of extraction space towards posterior segment. The vertical legs of the loop are 10mm each and the distance between the two vertical legs is 2mm [Table/Fig-3].

Conversion of Geometric Model to Finite Element Model

This geometric model was converted into finite element model. The element shape which was described in the model was tetra angular inform. These elements were connected to adjacent elements with the help of nodes, which join these elements in all directions. In order to establish the natural anatomy, the teeth were connected to the surrounding alveolar bone through the periodontal ligament. Therefore, convergence of all these nodes was established to make the connectivity of the model.

Material Property Data Representation

The different structures such as alveolar bone, dentition, periodontal ligament and various wires used in the finite element model of human maxilla were assigned their respective material properties.

Boundary Conditions

Boundary conditions for the maxilla: The model was restrained at the superior border of the maxilla in order to avoid any motion against the loads imposed on the dentoalveolar structures. The final model was done in such a way that the dimensions of all the teeth were similar to the normal values (Wheelers text book of dental anatomy). The inclination of the maxillary incisor teeth to the palatal plane was 112°. Thus the final model was confirmatory from an engineering point of view for this study.

Boundary conditions for the retraction loops: The element has three degrees of freedom at each node: it allows translations in the X and Y directions and a rotation about the Z-axis. In this study one end of the loop was totally restrained simulating the ligation of the arch wire to the bracket. The node at the other end was restrained similarly but permitted to move along the X-axis only similar to the arch wire in the molar tube.

RESULTS

Analysis was performed using ANSYS VERSION-11 software. The first step consists of bringing the anterior and posterior ends into proper position by specifying all translations and rotations at both ends except for the posterior horizontal displacement. At the end of this load step, anterior and posterior moments were present at

	Tear drop						T-loop						Open vertical loop					
	CI	LI	C	PM2	M1	M2	CI	LI	C	PM2	M1	M2	CI	LI	C	PM2	M1	M2
5-10	2.78E-05	3.02E-05	1.25E-04	1.09E-05	1.01E-05	1.34E-06	3.02E-05	3.21E-05	3.41E-05	1.40E-05	1.38E-05	1.33E-05	-.3E-05	3.75E-05	3.98E-05	1.94E-05	1.56E-05	1.45E-05
5-15	3.31E-05	3.40E-05	1.33E-04	1.20E-05	1.12E-05	1.03E-05	3.41E-05	3.64E-05	3.84E-05	1.75E-05	1.73E-05	1.45E-05	3.73E-05	3.98E-05	4.21E-05	2.11E-05	1.84E-05	1.68E-05
5-20	4.12E-04	4.34E-04	1.52E-04	1.32E-04	1.28E-04	1.19E-04	4.38E-04	4.50E-04	4.82E-04	2.00E-04	1.93E-04	1.67E-04	4.54E-04	4.73E-04	4.92E-04	2.32E-04	1.99E-04	1.77E-04
10-15	4.41E-04	4.76E-04	1.57E-04	1.47E-04	1.43E-04	1.27E-04	4.80E-04	5.01E-04	5.32E-04	2.13E-04	2.01E-04	1.93E-04	4.98E-04	5.34E-04	5.43E-04	2.42E-04	2.07E-04	1.97E-04
10-20	5.33E-04	5.53E-04	1.62E-04	1.63E-04	1.60E-04	1.45E-04	5.60E-04	5.70E-04	6.11E-04	2.42E-04	2.27E-04	2.11E-04	5.78E-04	5.82E-04	6.45E-04	2.59E-04	2.39E-04	2.13E-04
10-25	5.61E-04	5.91E-04	1.75E-04	1.85E-04	1.74E-04	1.63E-04	5.99E-04	6.10E-04	6.23E-04	2.67E-04	2.46E-04	2.36E-04	6.21E-04	6.45E-04	6.73E-04	2.75E-04	2.57E-04	2.43E-04
15-20	6.12E-04	6.54E-04	1.78E-04	1.95E-04	1.83E-04	1.79E-04	6.58E-04	6.78E-04	6.83E-04	2.76E-04	2.52E-04	2.40E-04	6.78E-04	6.93E-04	7.12E-04	2.84E-04	2.74E-04	2.54E-04
15-25	6.39E-04	6.71E-04	1.93E-04	2.04E-04	1.96E-04	1.92E-04	7.03E-04	7.34E-04	7.54E-04	2.94E-04	2.78E-04	2.64E-04	7.32E-04	7.45E-04	7.93E-04	3.04E-04	2.95E-04	2.71E-04
15-30	7.98E-04	8.29E-04	2.13E-04	2.31E-04	2.28E-04	2.16E-04	8.32E-04	8.52E-04	8.83E-04	3.13E-04	2.85E-04	2.75E-04	8.43E-04	8.54E-04	9.01E-04	3.47E-04	3.11E-04	2.89E-04

[Table/Fig-7]: Crown tip in M-D direction for the 3 different loops
CI- Central Incisor; LI- Lateral Insisor; C- Canine; PM2- Second Pre Molar; M1- First Molar; M2- SecondMolar

	Tear drop						T-loop						Open vertical loop					
	CI	LI	C	PM2	M1	M2	CI	LI	C	PM2	M1	M2	CI	LI	C	PM2	M1	M2
5-10	2.78E-05	3.02E-05	1.25E-04	1.09E-05	1.01E-05	1.34E-06	3.02E-05	3.21E-05	3.41E-05	1.40E-05	1.38E-05	1.33E-05	-.3E-05	3.75E-05	3.98E-05	1.94E-05	1.56E-05	1.45E-05
5-15	3.31E-05	3.40E-05	1.33E-04	1.20E-05	1.12E-05	1.03E-05	3.41E-05	3.64E-05	3.84E-05	1.75E-05	1.73E-05	1.45E-05	3.73E-05	3.98E-05	4.21E-05	2.11E-05	1.84E-05	1.68E-05
5-20	4.12E-04	4.34E-04	1.52E-04	1.32E-04	1.28E-04	1.19E-04	4.38E-04	4.50E-04	4.82E-04	2.00E-04	1.93E-04	1.67E-04	4.54E-04	4.73E-04	4.92E-04	2.32E-04	1.99E-04	1.77E-04
10-15	4.41E-04	4.76E-04	1.57E-04	1.47E-04	1.43E-04	1.27E-04	4.80E-04	5.01E-04	5.32E-04	2.13E-04	2.01E-04	1.93E-04	4.98E-04	5.34E-04	5.43E-04	2.42E-04	2.07E-04	1.97E-04
10-20	5.33E-04	5.53E-04	1.62E-04	1.63E-04	1.60E-04	1.45E-04	5.60E-04	5.70E-04	6.11E-04	2.42E-04	2.27E-04	2.11E-04	5.78E-04	5.82E-04	6.45E-04	2.59E-04	2.39E-04	2.13E-04
10-25	5.61E-04	5.91E-04	1.75E-04	1.85E-04	1.74E-04	1.63E-04	5.99E-04	6.10E-04	6.23E-04	2.67E-04	2.46E-04	2.36E-04	6.21E-04	6.45E-04	6.73E-04	2.75E-04	2.57E-04	2.43E-04
15-20	6.12E-04	6.54E-04	1.78E-04	1.95E-04	1.83E-04	1.79E-04	6.58E-04	6.78E-04	6.83E-04	2.76E-04	2.52E-04	2.40E-04	6.78E-04	6.93E-04	7.12E-04	2.84E-04	2.74E-04	2.54E-04
15-25	6.39E-04	6.71E-04	1.93E-04	2.04E-04	1.96E-04	1.92E-04	7.03E-04	7.34E-04	7.54E-04	2.94E-04	2.78E-04	2.64E-04	7.32E-04	7.45E-04	7.93E-04	3.04E-04	2.95E-04	2.71E-04
15-30	7.98E-04	8.29E-04	2.13E-04	2.31E-04	2.28E-04	2.16E-04	8.32E-04	8.52E-04	8.83E-04	3.13E-04	2.85E-04	2.75E-04	8.43E-04	8.54E-04	9.01E-04	3.47E-04	3.11E-04	2.89E-04

[Table/Fig-8]: Root tip in M-D direction for the 3 different loops
CI- Central Incisor; LI- Lateral Insisor; C- Canine; PM2- Second Pre Molar; M1- First Molar; M2- SecondMolar

	Tear drop						T-loop						Open vertical loop					
	CI	LI	C	PM2	M1	M2	CI	LI	C	PM2	M1	M2	CI	LI	C	PM2	M1	M2
5-10	1.72E-04	1.25E-04	3.31E-05	3.12E-06	2.74E-05	1.40E-05	2.43E-04	2.13E-04	3.56E-05	3.53E-06	2.98E-05	1.77E-05	4.52E-04	4.00E-04	3.87E-05	3.82E-06	3.33E-05	2.88E-05
5-15	2.11E-04	1.33E-04	3.87E-05	3.56E-06	3.29E-05	1.50E-05	2.72E-04	2.33E-04	4.11E-05	3.72E-06	3.39E-05	1.93E-05	4.87E-04	4.21E-04	4.43E-05	3.99E-06	3.41E-05	3.23E-05
5-20	2.37E-04	1.52E-04	4.01E-05	1.10E-05	4.34E-05	1.94E-05	2.95E-04	2.44E-04	4.43E-05	1.45E-05	4.56E-05	2.11E-05	5.21E-04	4.44E-04	4.96E-05	3.55E-05	1.20E-04	5.82E-05
10-15	2.40E-04	1.57E-04	4.45E-05	1.43E-05	4.50E-05	2.00E-05	2.99E-04	2.46E-04	4.78E-05	1.95E-05	4.77E-05	2.77E-05	5.30E-04	4.55E-04	5.01E-05	4.67E-05	1.22E-04	6.22E-05
10-20	2.68E-04	1.62E-04	5.12E-05	1.76E-05	4.65E-05	2.14E-05	3.17E-04	2.68E-04	5.79E-05	2.33E-05	4.88E-05	2.94E-05	5.54E-04	4.84E-04	5.90E-05	4.99E-05	1.34E-04	6.26E-05
10-25	3.02E-04	1.75E-04	5.50E-05	2.11E-05	5.42E-05	2.30E-05	3.46E-04	2.91E-04	5.99E-05	2.64E-05	5.55E-05	3.42E-05	5.96E-04	5.03E-04	6.10E-05	5.18E-05	1.40E-04	7.06E-05
15-20	3.20E-04	1.78E-04	5.97E-05	2.30E-05	5.67E-05	2.35E-05	3.56E-04	2.97E-04	6.45E-05	2.75E-05	5.79E-05	3.54E-05	5.83E-04	5.10E-04	6.77E-05	5.81E-05	1.46E-04	7.27E-05
15-25	3.38E-04	1.93E-04	6.34E-05	2.75E-05	6.64E-05	2.81E-05	3.74E-04	3.13E-04	6.94E-05	3.23E-05	6.77E-05	4.07E-05	6.19E-04	5.15E-04	7.45E-05	6.10E-05	1.69E-04	7.39E-05
15-30	3.73E-04	2.13E-04	6.57E-05	2.88E-05	6.88E-05	3.01E-05	3.98E-04	3.18E-04	7.01E-05	3.98E-05	7.00E-05	4.32E-05	6.71E-04	5.47E-04	7.80E-05	6.87E-05	1.81E-04	7.87E-05

[Table/Fig-8]: Root tip in vertical direction for the 3 different loops
CI- Central Incisor; LI- Lateral Insisor; C- Canine; PM2- Second Pre Molar; M1- First Molar; M2- SecondMolar

the two ends, with no horizontally active forces. These moments were calculated for all alpha and beta combinations for each type of retraction loop used in this study.

The second step consists of posterior activation of the wire along the ho-rizontal plane such that the legs of the loop are opened by 1mm in the clinical situation and forces on individual teeth are calculated. Using these force values moments and M/F ratios of anterior and posterior segments are calculated and at the same time movement of individual teeth in both horizontal and vertical direction are calculated.

Interpretation of results

The nodal displacement at the incisal edge, cervical margin, mid root region at the apex was analysed and the results were tabulated.

Displacement of the crown tip and root tip of the central incisor, lateral incisor, canine, second premolar, first molar, second molar was studied to evaluate the type of tooth movement.

Results from [Table/Fig-4-6] shows that as alpha and beta angulations increases both alpha and beta M/F ratio decreases for all three loops. Alpha and beta M/F ratios of T-loop are more than Teardrop loop and less than Open vertical loop.

It is inferred from [Table/Fig-7-9] that as angulations increases intrusive or extrusive movements increases. Intrusion can be seen in anteriors and in the case of posteriors, extrusion seen due to moment differential. Intrusive or extrusive movements of T-loop are more than Teardrop loop and less than open vertical loop.

Results from [Table/Fig-7-9] shows that as angulations increases crown tip or root tip movement increases in horizontal direction. For both anteriors and posteriors, crown tip will move in distal direction and root tip in mesial direction. Crown tip or root tip movements T loop are more than Teardrop loop and less than Open vertical loop.

DISCUSSION

Space closure in extraction cases in PEA system is achieved by the judicious use of sliding mechanics - friction mechanics, or loop mechanics- frictionless mechanics. According to Staggers et al.,[3], frictionless mechanics involving the use of retraction loops in continuous arch wire or in segmental form offers more controlled tooth movement in comparison to friction mechanics.

To analyse the forces and moments produced during activation of the retraction loop different techniques such as experimental procedures, numerical and analytical methods and FEM analysis are used [7,8]. The effect of these forces on the tooth and surrounding structures have been studied using photoelastic, laser holographic and FEM methods. FEM has the following advantages-very accurate, non invasive, actual physical properties of the materials involved can be simulated, thus simulating the oral environment invitro and the study can be repeated as many times as the operator wants. In a FEM study for tooth movement, Young's modulus and Poisson's ratio are the essential parameters which are required as mathematical inputs for generating the finite element model, any alteration would affect the outcome of results [9].

The three dimensional FEM model used in the study provides the freedom to simulate the orthodontic force system applied clinically and allows analysis in the response of the dentition to the orthodontic load in three dimensional spaces [6,10-13]. In the present study, the moments and M/F ratios produced while simulating the insertion of the appliance into the brackets were calculated and tabulated for the three retraction loops at varying alpha and beta part angulations combinations. In the second part of study, movements of anterior and posterior teeth were calculated.

The M/F ratio of the applied force and moment determines the type of movement or the center of rotation. In the present study, in order to simulate the exact nature of oral environment and achieve accurate results, we improved the three dimensional FE model by using a range of 63282 to 65507 ten noded tetrahedral type elements for enamel, dentin, cementum and alveolar bone. Also PDL model has been refined by using around 2106 shell elements. In our study we used PRO/ENGINEER 11, ANSYS FEM software which is more advanced than the old versions used and were able to analyse both ends of the retraction loop.

Faulker et al., [2] assessed vertical loops with and without angulations. The wire used was 0.016" x 0.022" stainless steel. The observation for the gabled loops was that the forces required for activation of 1mm was high. In our study due to the use of higher wire cross section the forces produced per mm of activation was high. In our study increase in alpha and beta angulations causes increase in momentum values which is correlated with study conducted by Haskell [10].

Young-Il chang et al., [9] conducted a study to compare the effects of a multiloop edgewise archwire on distal en masse movement with a continuous plain ideal arch wire. They created FEM of the maxillary dentition in which the second permanent molars had been extracted. In our study second molars and trans palatal arch are also included to create ideal group A anchorage. The loops are placed off center by 2mm towards posterior segment which will also helps in increasing posterior anchorage.

Andrew J. Kuhlberg et al.,[14] conducted a cephalometric study to compare measured tooth movements with the theoretical force system exerted by differential moment T- loops. This study shows less forward movement of posteriors with maximum retraction of anteriors and this confirms with our study. As α and β angulation increases, alpha M/F ratio decreases. There is no definite pattern of decrease in M/F ratios by altering angulations. Higher M/F ratios than 10:1 will cause more root movement. As M/F ratio decreases and reaches near value 10:1, bodily movement of teeth can be seen. When it is reduced less than value 10:1 more crown movement than root can be seen.

α and β M/F ratios of T-loop are more than Tear drop loop and less than open vertical loop. Bodily movement of anterior teeth can be seen for Tear drop loop at 10-20 (α and β) angulations, for T- loop at 15-20 angulations and for open vertical loop at 15-25 angulations where M/F ratios are near 10:1. Bodily movement of posterior teeth can be seen for Tear drop loop at 15—20 (α and β) angulations, for T loop at 15-30 angulations. Bodily movement of posterior teeth is not possible in the case of open vertical loop.

α And β Momentum

As α and β angulations increases both α and β momentum increases. There is no definite pattern of increase in alpha moments. Alpha moments of T- loop are more than Tear drop loop and less than open vertical loop.

Movement of Root Tips in Vertical Direction

Vertical forces are intrusive and extrusive forces acting on the anterior or posterior teeth. These forces generally result from unequal alpha and beta moments. When the beta moment is greater than alpha moment, an intrusive force acts on the anterior teeth while extrusive force act on the posterior teeth. When the alpha moment is greater than beta moment, extrusive forces acts on the anterior teeth while intrusive forces act on the posterior teeth.

In this study, since beta moments are greater than alpha moments intrusive forces acts on the anterior teeth and extrusive forces acts on posterior teeth. Among anteriors lateral incisor shows more intrusion than canine and less than central incisor. Among posteriors, second molar shows more extrusion than first premolar and less than first molar.

As α and β angulations increases either intrusion or extrusion increases. Among three loops T- loop shows more either intrusion or extrusion than Tear drop loop and less than Open vertical loop.

Movement of Crown Tip and Root Tip in Horizontal Direction:

As α and β angulations increases movement of either crown tip or root tip increases. Among anteriors movement of either crown tip or root tip of lateral incisor is more than central incisor and less than canine. Among posteriors movement of either crown tip or root tip of first molar is more than second molar and less than second premolar.

Among three loops movement of either crown tip or root tip of the anteriors and posteriors of T- loop is more than Tear drop loop and less than Open vertical loop. When M/F ratios are near to12:1 movement of root tip in horizontal direction will be more than crown tip.

When M/F ratios are near to 10:1, both crown tip and root tip moves nearly to the same extent and leads bodily motion. When M/F ratios are decreasing less than 10:1 movement of crown tip will be more than root tip in horizontal direction which leads to tipping.

Among anterior crown tip moves in distal direction and root tip in mesial direction and among posteriors also crown tip moves in distal direction and root tip in mesial direction which coincides with the study conducted by staggers [3].

CONCLUSION

Tear drop loop was the best choice among the three retraction loops because of the advantages it has over the other two in relation to the anchorage control, intrusive or extrusive movement of root tip and less forward movement of posteriors compared to anteriors. From the results of our study we conclude that among three loops Tear drop loop with alpha and beta angulations of 10-20 is preferable.

Limitations and future scope

The results are based on the fact that the thickness of the periodontal ligament is uniformly 0.25 mm. However, the thickness of the PDL is 0.25(±50 percent). This difference might induce unexpected tooth movements. After orthodontic force is applied, histological changes can alter the physical properties of the tissues and therefore Young's modulus and poisson's ratio are not constant material propertie, and hence the secondary response could be different from initial response of the PDL. The center of resistance of a tooth is dependent on the root length and morphology, the number of roots and the level of alveolar bone support which varies from individual to individual. In this study 0.019"x0.25" stainless steel wire is used which will cause higher forces. The study can be improved by increasing the number of nodes and elements. Therefore the M/F values generally advocated to obtain orthodontic tooth movement should be used only as guidelines.

All these factors should be included in future studies of FEM to simulate the nearest possible clinical condition and study orthodontic tooth movement. The future improvements in software and updated versions could help in refinement of meshing process and creating a more accurate 3D FE model.

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PARTICULARS OF CONTRIBUTORS:

1. Reader, Department of Orthodontics and Dentofacial Orthopaedics, St. Joseph Dental College, Duggirala, Eluru, Andhra Pradesh, India.
2. Assistant Professor, Department of Orthodontics and Dentofacial Orthopaedics, St. Joseph Dental College, Duggirala, Eluru, Andhra Pradesh, India.
3. Reader, Department of Orthodontics and Dentofacial Orthopaedics, Thai Moogambigai Dental College, Chennai, India.
4. Professor, Department of Orthodontics and Dentofacial Orthopaedics, St. Joseph Dental College, Duggirala, Eluru, Andhra Pradesh, India.
5. Consultant Orthodontist,Chennai, India.
6. Consultant Orthodontist,Chennai, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Supradeep Kumar,
Flat# 102, RVS Dwaraka Clusters, Behind Andhra Bank, Ashok Nagar, Eluru,W.G.Dist,
Andhra Pradesh-534002, India.
Phone: 07416581005, 07416581006, E-mail: supradeep_k@yahoo.com

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