ASSESSMENT AND COMPARISON OF LOAD DEFLECTION RATE,FORCE PRODUCTION OF T-LOOP WITH HELIX AND CONVENTIONAL T-LOOP:A COMPARATIVE FEM STUDY.

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Abstract:

This study investigates the biomechanical performance of T-loop designs with helices in orthodontic applications, focusing on their load deflection rate at varying activation levels. The results demonstrate a reduction in the load deflection rate at 1 mm, 2 mm, and 3 mm activations, highlighting the enhanced control and efficiency of force delivery in orthodontic treatments. The incorporation of helices in T-loop designs contributes to improved biomechanical behavior, offering clinicians a more predictable and effective tool for tooth movement. These findings underscore the potential of T-loop designs with helices to optimize orthodontic mechanics, particularly in cases requiring precise force application. Further research is recommended to explore their clinical implications and long-term performance in diverse treatment scenarios.

Keywords:

T-loop with helix,Conventional T-loop,Load-deflection rate,Force production,Finite Element Method (FEM),Orthodontic space closure,Biomechanical efficiency,Activation levels,Orthodontic mechanics,Stress distribution,Periodontal ligament,Orthodontic force control,Loop mechanics,

INTRODUCTION

Non-extraction treatment plans are in priority among patients and orthodontists nowadays, extraction is still a common way to treat malocclusions such as tooth size discrepancy, camouflage of skeletal problems, reaching functional and stable occlusion with maximum aesthetics, etc. Space closure is the most important stage in the extraction treatment plans.[1]

Retraction or space closure after extraction in labial as well as lingual orthodontics can be done either by friction/sliding mechanics or frictionless/loop mechanics. The drawback of sliding mechanics in terms of overcoming the amount of friction generated between the bracket and the wire interface before bringing effective tooth movement can be avoided in frictionless/loop mechanics.[2]

In contemporary labial orthodontics, many closing loops are being used for retraction such as a vertical closing loop, teardrop loops, T-loops, L-loops, mushroom loops, opus loops, keyhole loop, and open-vertical loop[1].To estimate the efficacy of any loop in a clinical situation, it is important to determine its biomechanical characteristics like force, moment, and moment to force ratio.

The biomechanics of tooth movement is based on the moment of force (MF) applied on the bracket which is generated due to application of force away from the centre of resistance (CRes) (MF = Force ×perpendicular distance of the bracket from CRes). M/F ratio obtained as a ratio between counter balancing moment (Mc) given to negate the unwanted effect of MF and the force. This ratio determines the type of tooth movement possible like M/F ratio of 7:1 denotes tipping movement and 10:1 is seen in bodily and 12:1 in root movement[1].

The efficacy of the loops in the labial technique has been extensively researched in the last few decades. Closed helical loop was simple in its design and T-loop provided better torque control in anterior teeth in a clinical study. Hence, it was decided to determine biomechanical properties of conventional T-loop and T loop with helix in the present study. Quantitative determination of the biomechanical characteristics of loops is not possible clinically; however, these mechanical properties can be determined by newer and precise examination tools, i.e., finite element method (FEM).[3]

Finite Element Analysis (FEA) was introduced by R. Courant in 1943. It is a powerful computer simulation tool in solving stress-strain problems in the mechanics of solids structures in engineering. The term “finite element” was coined by Clough in 1960. In orthodontics, FEM has been used successfully to model the application of forces to single and multi-tooth systems, to show the area of bone remodelling, due to various types of tooth movements like tipping, bodily movement, rotation, retraction etc.

The FEM principle is based on the division of a complex structure into smaller sections called elements in which physical properties, such as the modulus of load deflection, are applied to indicate the object response against an external stimulus such as an orthodontic force. Reduce load deflection rate where result in lesser trauma to the periodontium, shorter lag phase and lesser root resorption, which is required for orthodontic tooth movement.

There are two main methods for space closure:

- frictional mechanics
- frictionless mechanics

In frictional mechanics, space is closed by sliding wire in the slot of brackets and tubes, so that the main part of the applied force is lost due to friction and anchorage preservation is thus critical. Frictionless mechanics are performed by continuous arch wires with loops or segmented arch techniques. Segmented arch mechanics provides more efficient retraction in the maximum anchorage cases. On the other hand, loops are useful for space closure in friction less mechanics. Several methods have been used to analyse different characteristics of the loops such as stress-strain, M/F, design, material, which are generally divided into two categories:[4]

(A) Experimental methods

(B) Analytical and numerical methods, which include finite element methods (FEM) and non-finite element methods.

The T-loop and modified T-loop are two important concepts in finite element method (FEM) studies, particularly in the context of structural analysis and design. These loops play a significant role in modelling and analysing complex structures under various loading conditions. Let's delve into their introduction and how they are used in FEM studies:

Design of T-loop

The T-loop is a fundamental concept in finite element analysis that represents the interaction between structural members in a system.

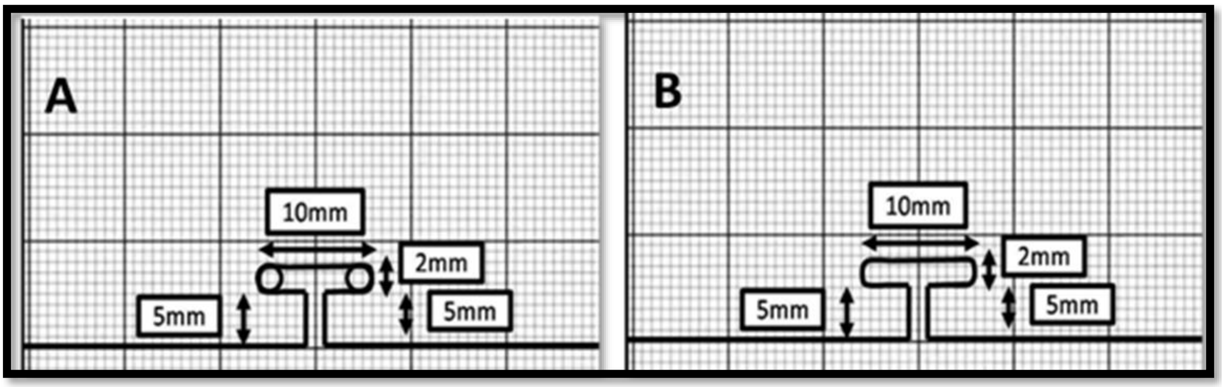

Figure1 (A) T-Loop with Helix (B) Conventional T-Loop

It typically involves two or more structural components connected at a joint or intersection point.[5]

Role of T-Loop in FEM Studies:

The T-loop concept is commonly used in analysing frames, trusses, and other structural systems where load transfer and stress distribution are critical considerations. The T-loop is utilized to model connections or joints between structural elements accurately. By defining T-loops, engineers can simulate how loads are transferred between connected members and analyse stress concentrations, deformation, and overall structural behaviour.

T-loops help in understanding the response of a structure to applied loads, enabling engineers to optimize designs for strength, stability, and performance[5].

Challenges with Traditional T-Loops:

1. While the T-loop concept is effective, traditional implementations may oversimplify complex joint behaviour.
2. They may not account for variations in load distribution, material properties, or geometric configurations that affect the actual behaviour of joints in real-world structures.This limitation led to the development of modified T-loops to enhance the accuracy and reliability of FEM analyses.

Introduction to Modified T-Loop:

Modified T-loop refers to an improved or refined approach to modelling joints and connections in finite element analysis. It incorporates advanced techniques and algorithms to capture more realistic joint behaviour and load transfer mechanisms.

The modifications may include considering non-linear effects, material nonlinearity, contact interactions, and geometric irregularities that influence joint performance.

Benefits of Modified T-Loop in FEM Studies:

1. Enhanced Accuracy: Modified T-loops provide more accurate predictions of stress distribution, deformation, and failure modes in complex structures. Improved Design
2. Optimization: Engineers can use modified T-loops to optimize designs by considering a wider range of factors that affect joint behaviour.
3. Better Simulation of Real-World Conditions: By accounting for non-linearities and other complexities, modified T-loops enable FEM models to simulate real-world structural responses more effectively[5].

Applications of T-Loops and Modified T-Loops:

T-loops and modified T-loops find extensive applications in civil engineering, mechanical engineering, aerospace, and other fields where structural analysis is crucial. They are used in designing buildings, bridges, aircraft, automotive components, and various mechanical systems to ensure structural integrity and performance. The introduction of T-loops and their evolution into modified T-loops have significantly advanced the capabilities of finite element method studies. These concepts are indispensable tools for engineers and researchers seeking to analyse, optimize, and design complex structures with confidence and accuracy[7]. Finite element method was used for the first time, about five decades ago in the aerospace industry to determine the amount of stress on the fuselage.

1. It entered into medical and dental researches in 1970s. Orthodontists used FEM for analysing the stress on various structures such as periodontal ligament, TMJ
2. Cranium and jaws
3. Brackets and adhesives

4. and others. With the rapid development of technology, it is also possible to use FEM in personal computers, several software such as NISA-DISPLAY ANSYS, ALGOR and MSC PATRAN-NASTRAN are available.[8].

The efficacy of Orthodontic loops is analyzed through experimental and analytical methods, such as finite element method (FEM). FEM is a mathematical model that predicts mechanical phenomena like force, strain, stress, and their interaction with each other.

Loop configuration incorporating two helices in the horizontal segment of the T loop, which increases the length of wire used. This design is intended to improve the range of action, load/deflection rate, loop recovery and moments produced. Overall, the T loop with helix is a novel and innovative approach to loop design.

Therefore, this study to evaluate the efficacy of the T loop with helix over the conventional T loop by assessing their load deflection rate under three different activations and loop configurations, as well as analyzing stress distribution and deformation in the periodontal ligaments and surrounding using finite element analysis (FEA). This study also determines the effects of design stiffness and material stiffness (stainless steel) on the force and load deflection rate to assess their efficacy and suitability for clinical use.

In orthodontics, closing loops such as T-loops with or without helices are widely used for space closure, root control, and providing controlled tooth movement. The mechanical properties of these loops, such as load-deflection rate and force production, play a critical role in determining their efficiency and clinical applicability. While the conventional T-loop has been a standard choice, the addition of helices may influence its mechanical behavior by altering force delivery and flexibility.

Despite the frequent use of these loops in clinical practice, limited comparative research exists evaluating the performance differences between T-loops with helices and conventional T-loops. Understanding these differences is essential to improve treatment outcomes and optimize loop design for specific orthodontic requirements.

This study is needed to:

1. **Assess Load-Deflection Rate:** Evaluate how the inclusion of helices impacts the load-deflection characteristics, which influence the level of force delivered during activation and deactivation.
2. **Analyze Force Production:** Compare the force levels produced by the two types of T-loops, ensuring that they fall within the optimal biological range to prevent adverse effects such as root resorption or patient discomfort.
3. **Enhance Clinical Decision-Making:** Provide orthodontists with evidence-based insights to select the most appropriate loop design for varying clinical situations, such as cases requiring precise force control or longer activation intervals.
4. **Contribute to Design Optimization:** Support further innovation in loop mechanics by understanding the role of helices in improving loop flexibility, activation range, and biomechanical efficiency.

By comparing the load-deflection rate and force production characteristics of T-loops with helices and conventional T-loops, this study will fill a critical knowledge gap and contribute to advancements in orthodontic biomechanics, ultimately benefiting both practitioners and patients.

AIM:

This study aims to assess and compare the Load deflection rate, force production of T-loop with helix and conventional T-loop on different length activation using finite element method.

OBJECTIVES:

1. To assess load deflection rate in T-loop with helix at 1 mm, 2mm, 3mm activation.
2. To assess force produced at anterior arm of T-loop with helix at 1 mm, 2mm, 3mm activation.
3. To assess load deflection rate in conventional T-Loop at 1mm, 2mm, 3mm activation.
4. To assess force produced at anterior arm of conventional T-loop with at 1 mm, 2mm, 3mm activation.
5. To compare the load deflection rate of T-loop with helix and conventional T-loop at different activations. (1mm,2mm,3mm)

NULL HYPOTHESIS:

There is no difference in load deflection rate, force production of T-loop with helix when compared with conventional T-loop.

MATERIALS AND METHODOLOGY

Armamentarium: For fabrication of loop

1. 0.017X0.025inch stainless steel wire
2. Pliers – no. 142 (Ribbon-arch or tweed)

   Pliers- no.139 (Bird beak)
3. Light wire cutter
4. Turret
5. Permanent marker
6. Glass plate

7. Graph sheet.

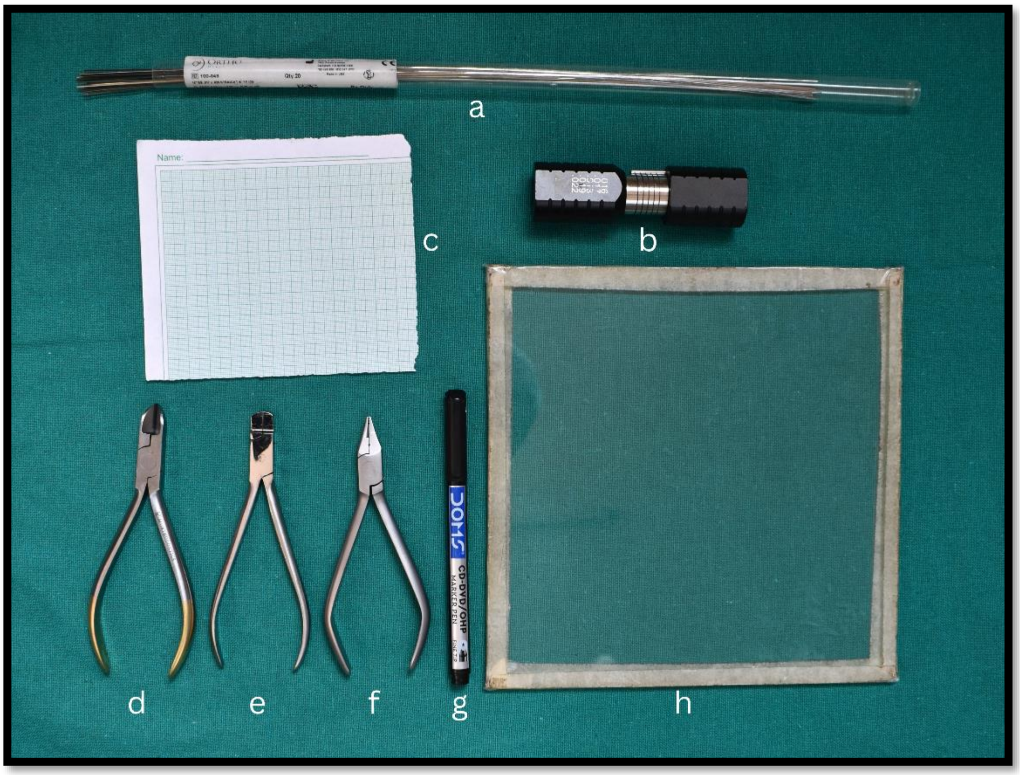

Figure 1 Armamentarium(a) 0.017X0.025inch stainless steel wire (b)Turret (c)Graph sheet (d)Light wire cutter (e)Pliers–no.142(Ribbon-arch or Tweed plier) (f) Pliers- no.139 (Bird beak) (g)Permanent marker (h)Glass plate

Method:

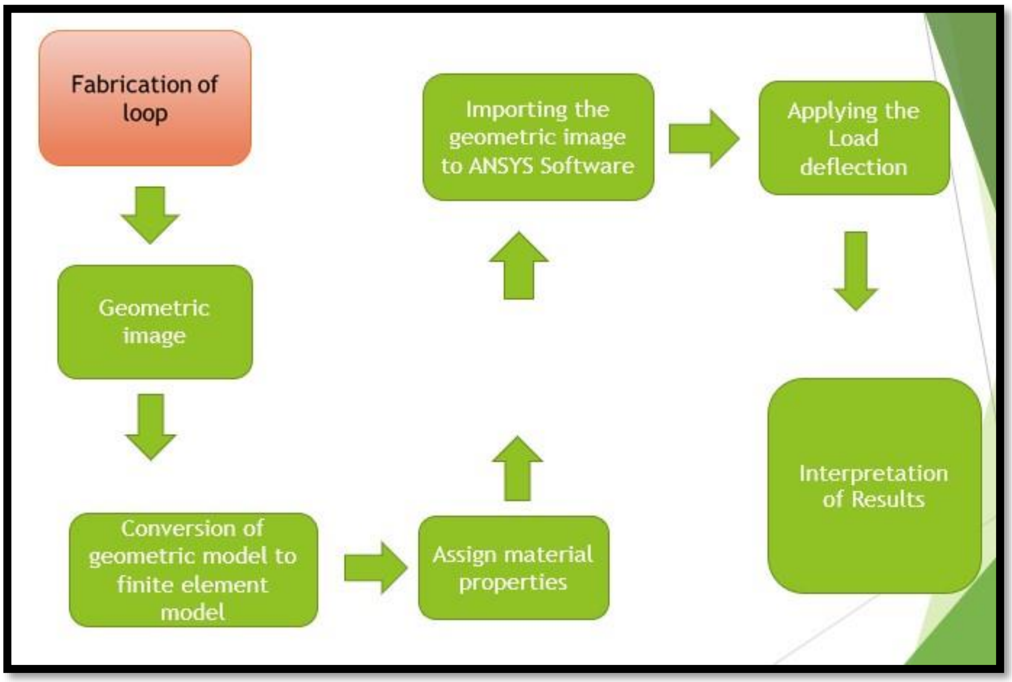

Figure 2 Steps of FEM Analysis

STEPS OF FEM ANALYSIS

1. Fabrication of loops to the exact measurement.
2. Construction of the geometric model using 3-D software Hypermesh 2019 is used for Creating Fe-models.Ansys 2017.2 is used for Analysis.
3. Conversion of geometric model to finite element model. Ansys 2017.2 is used for Analysis
4. Material property data representation: material properties were assigned.
5. Defining the boundary condition.
6. Application of force for different activations of the loop.
7. Evaluation of load deflection of the loops and force exerted.

Two groups of loops

Group A T-LOOP WITH HELIX.

Group B CONVENTIONAL T-LOOP

❖ Wire for the FEM analysis of load deflection in both the loop design 0.017 X 0.025-inch Stainless Steel wire used for T-loop.

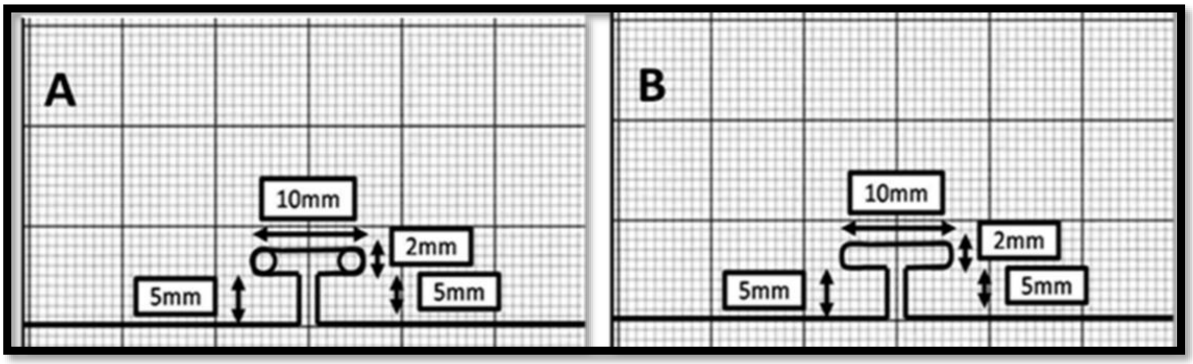

Figure 3(A)T-loop with helix(B) Conventional T- Loop

❖ The Young's modulus of the stainless-steel wire will be Elastic modulous = 200 GPa and the Poisson ratio is equal to 0.29

1. Fabrication of loops to the exact measurement

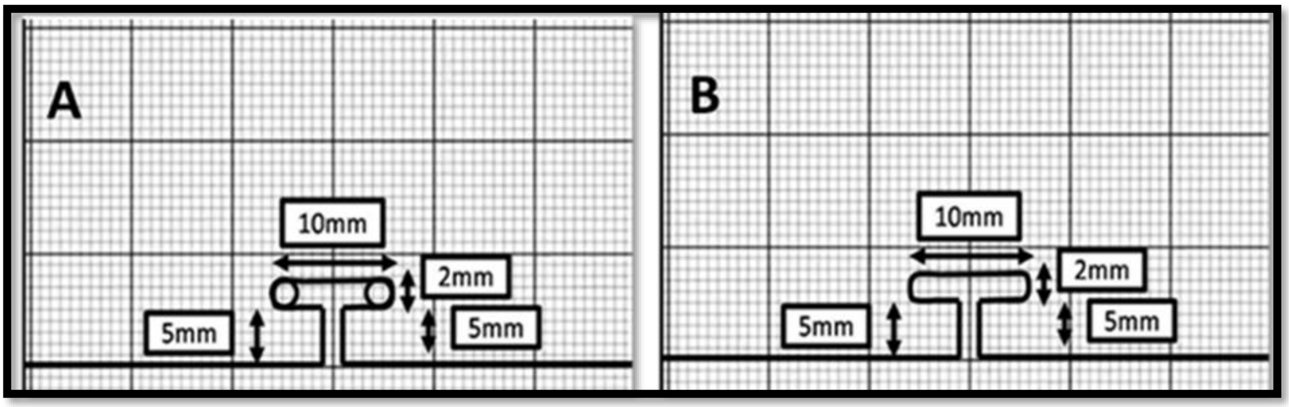

Figure 4 (A)T-loop with helix(B) conventional T-Loop

❖ For the FEM study basic design of two different T-loops will be as follows

1. T-loop with helix: horizontal loop of length 10mm and width of 2mm, Helix of 2mm at both the ends of horizontal loop and a vertical arm of 5mm length that is 2mm apart. (Figure10A)
2. Conventional T-loop: horizontal loop of length 10mm and width of 2mm and a vertical arm of 5mm length that is 2mm apart. (Figure 10 B)

- The dimensions of teeth for this model were simulated from data obtained through various dental literature. As the thickness o not the same all over, an average thickness of the periodontal ligament was assumed to be 0.25 mm which was generated around the model of the root. 3D model of T loop is created using Hypermesh 2019 is used and ANSYS 2017.2 used for analysis.
- 1D beam elements of rectangular 0.017 X 0.025inch ss is used.

2. Construction of the geometric model using 3-D software

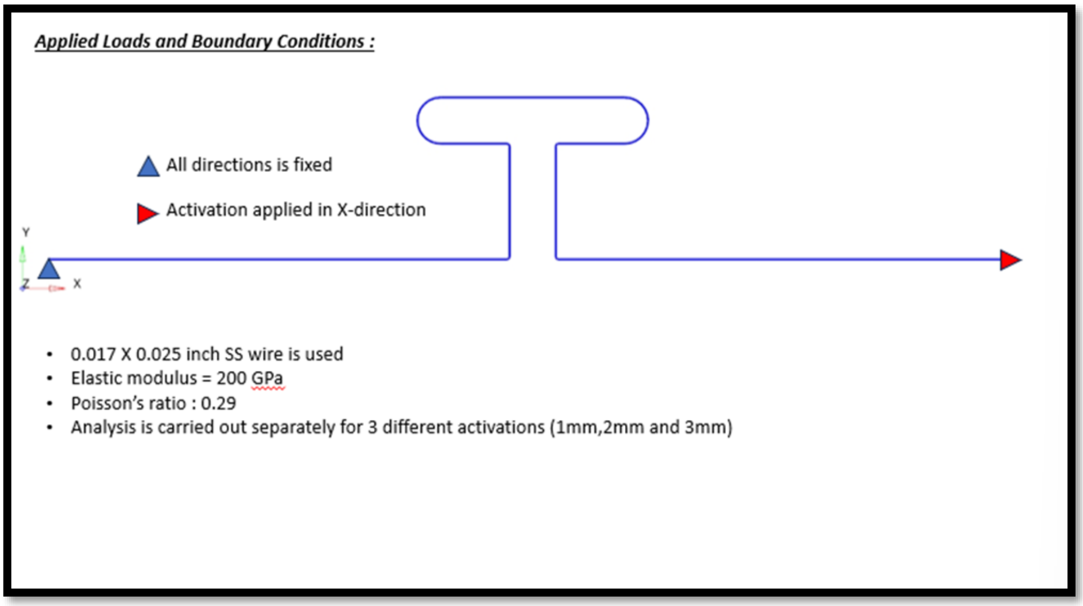

Figure 5 Applied Loads and Boundary Conditions

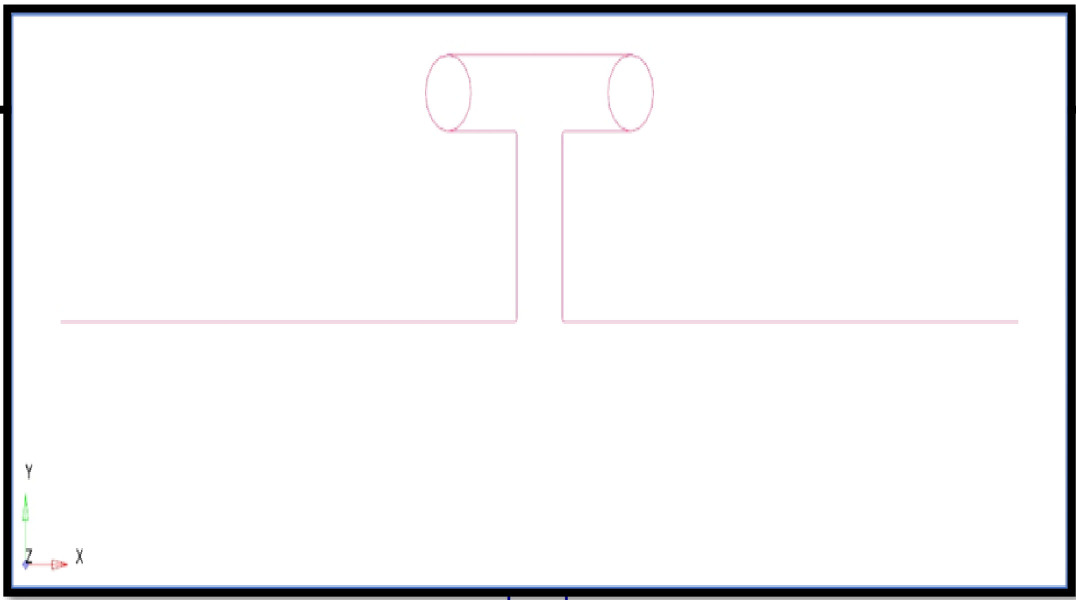

Figure 6 (A)Geometric Model of T-Loop with Helix

Figure 6(B) FE-Model of T-Loop with Helix

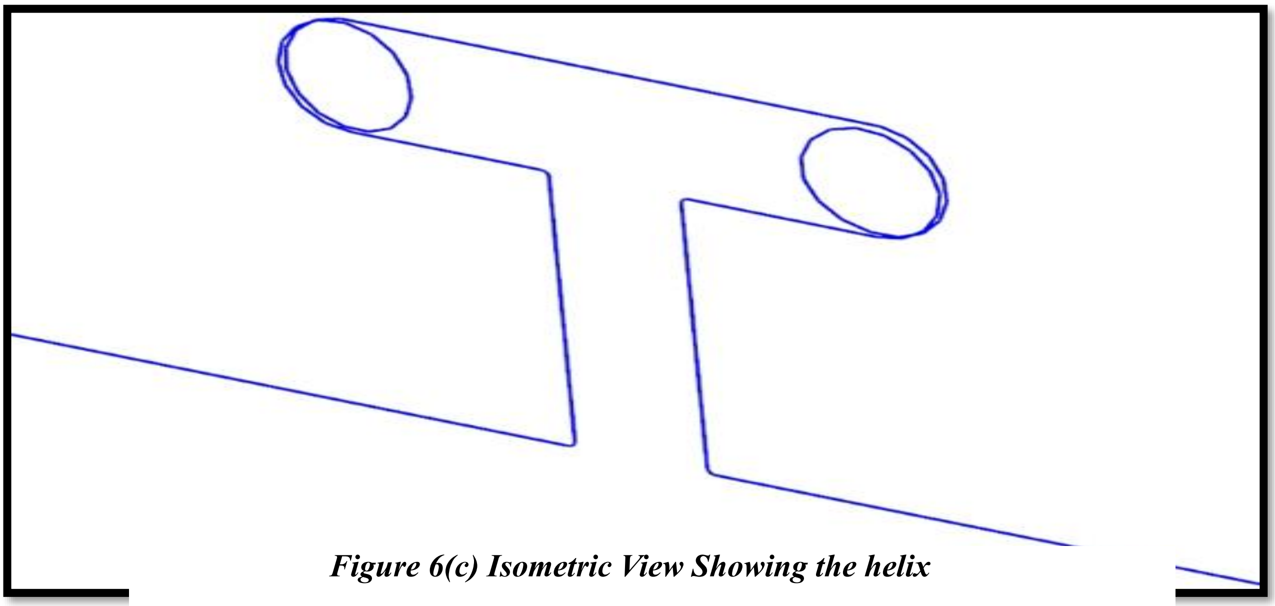

Figure 6(c) Isometric View Showing the helix

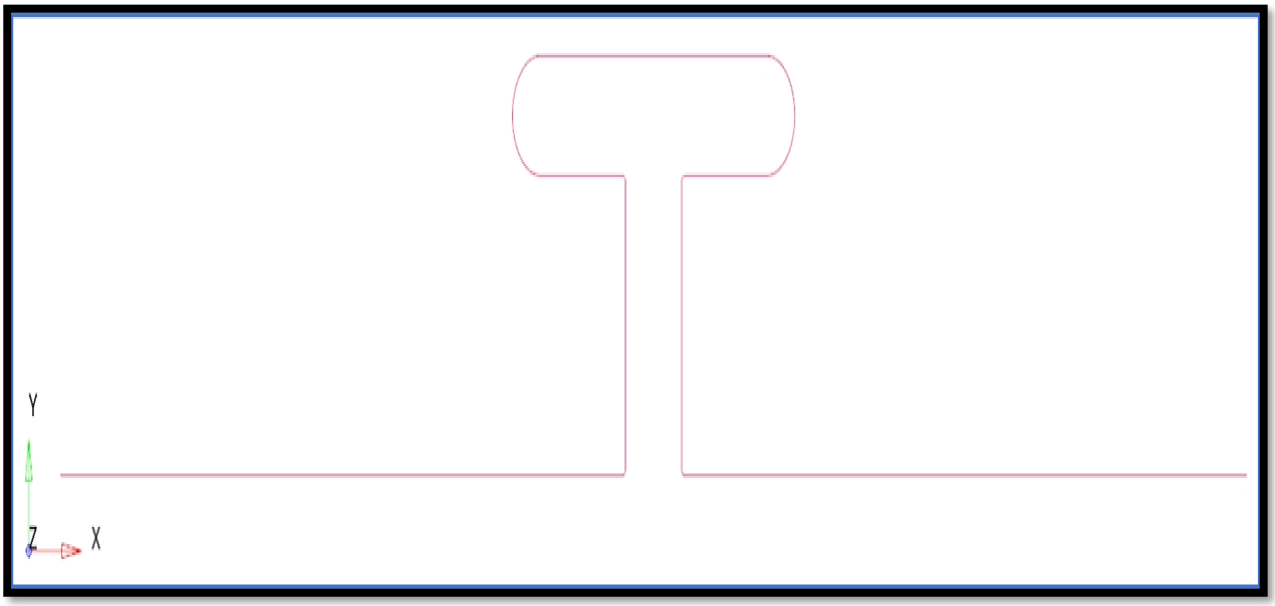

Figure 7 (A)Geometric Model of Conventional T- Loop

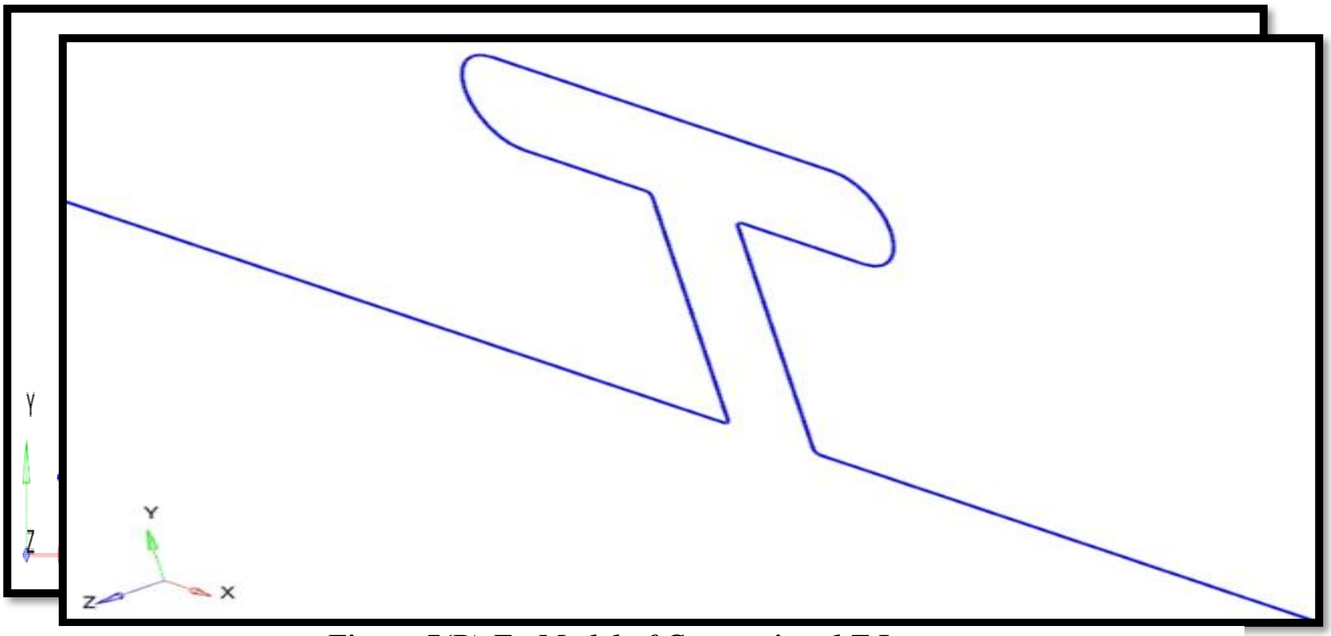

Figure 7(B) Fe-Model of Conventional T-Loop

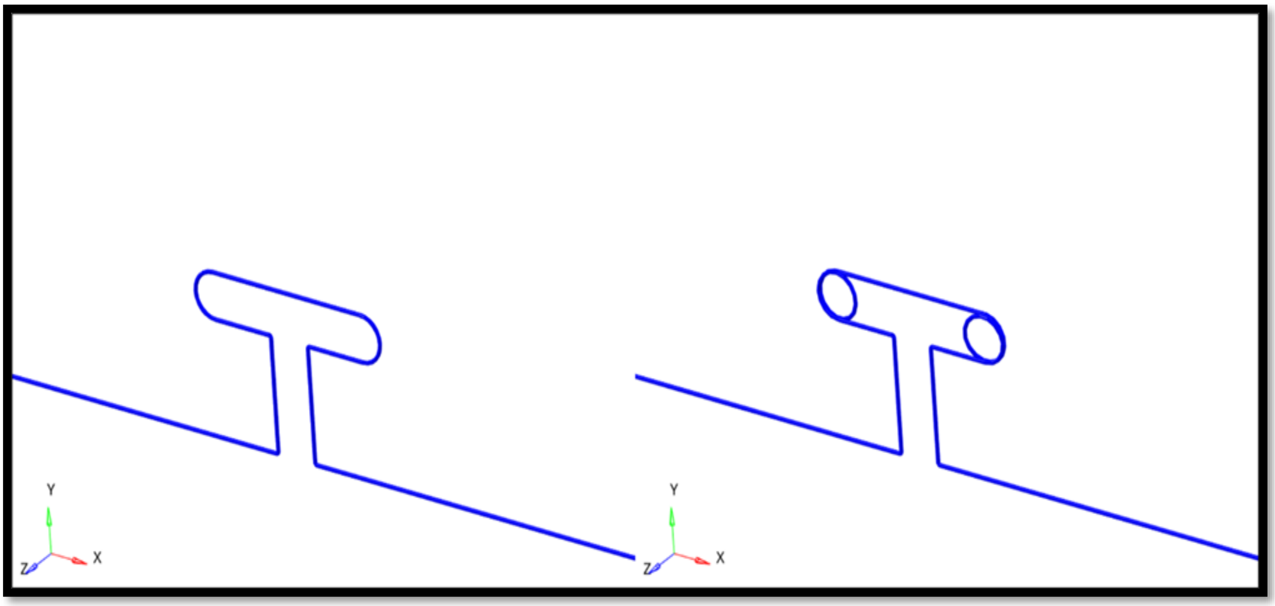

Figure 8 Different Planes of Conventional T-Loop and T-Loop with Helix

1D beam elements of rectangular 0.017 x 0.025-inch stainless steel were used.

Total Elements = 124

Total Nodes = 125

3. **Conversion of geometric model to finite element model. (Hypermesh 2019 is used for Fe model and ANSYS 2017.2)**

The finite element modelling is the representative of geometry in terms of finite number of element & nodes. This process is called discretization which intends to improve the accuracy of the results. Solid Model is divided into discrete parts called elements which may be tetrahedron, rectangular points or hexahedron for 3D analysis.

The ANSYS element library contains more than 100 different element types. We have used solid 124 and Solid 125 elements in this analysis. These elements are considered inter connected at joints which are called nodes or nodal points. The corner nodes are called primary external nodes. The additional nodes which occur on the sides of the elements are called secondary external nodes, which has fewer displacements than corner nodes.

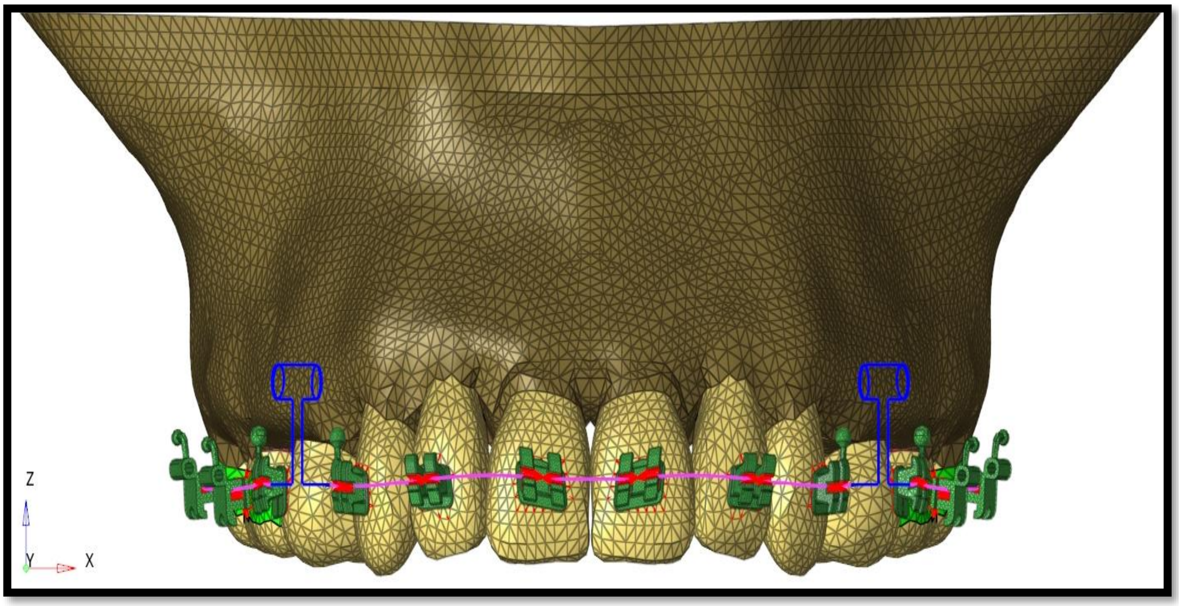

Figure 9(a) FEM Model T Loop with Helix (Bone geometry)

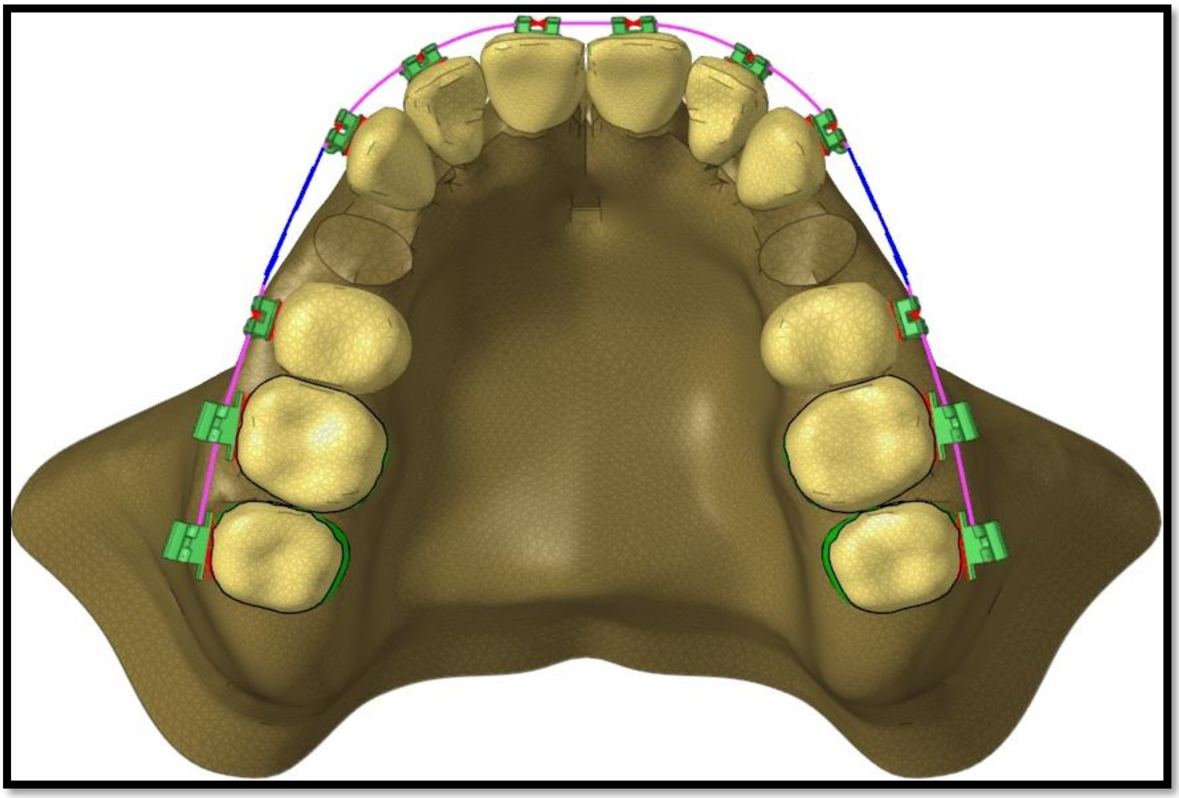

Figure 9(b) FEM Model (Bone geometry)

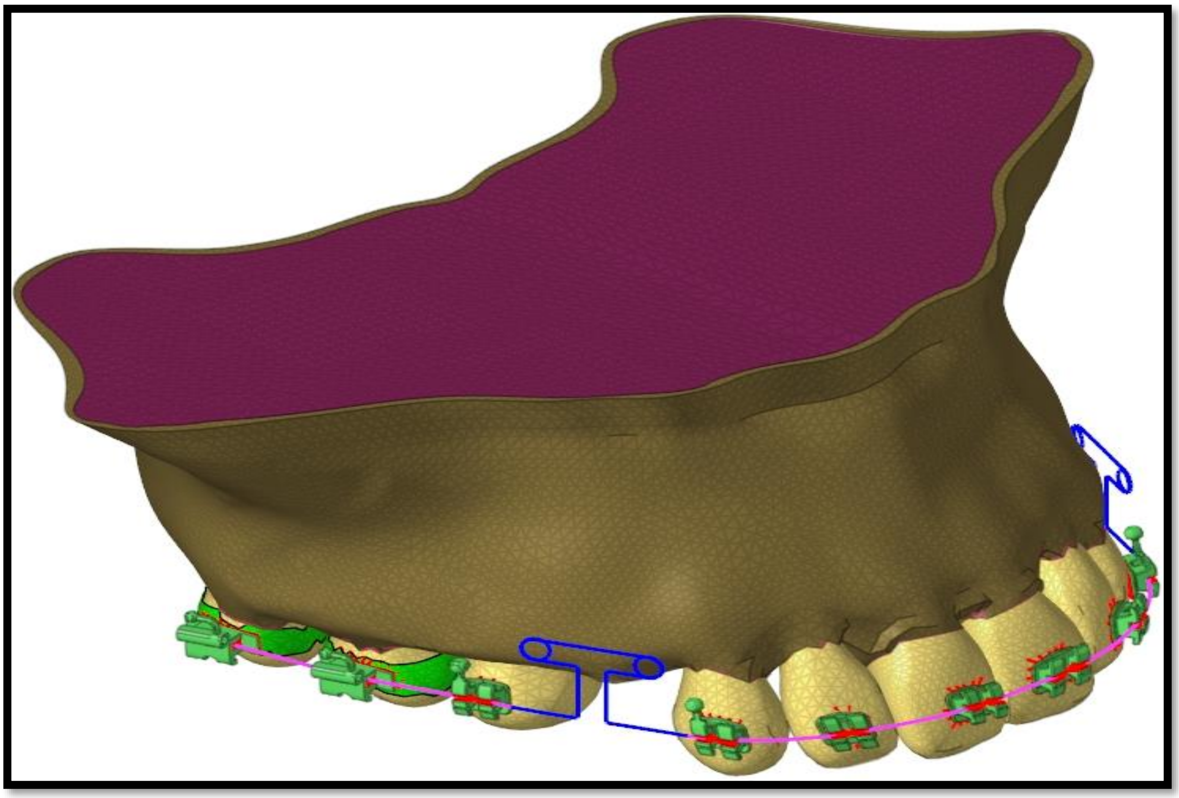

Figure 9(c) FEM Model T Loop with Helix

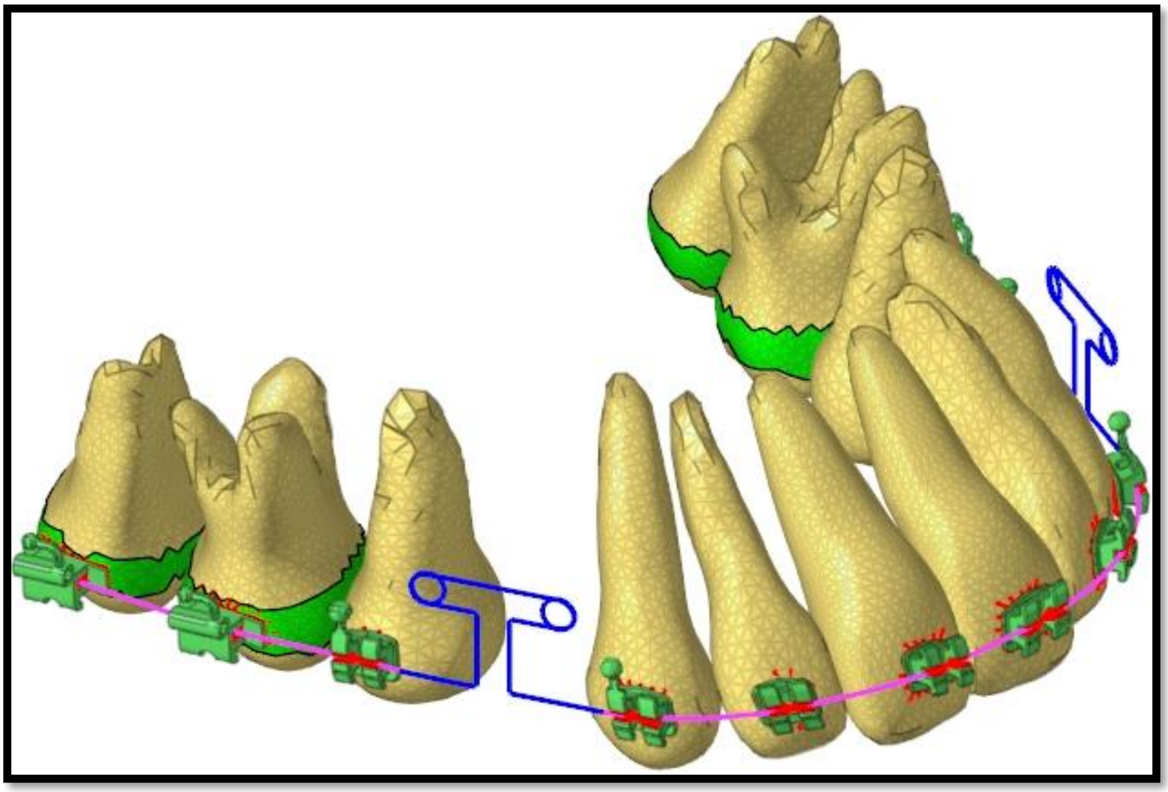

Figure 9(d) FEM Model T Loop with Helix (dental geometry)

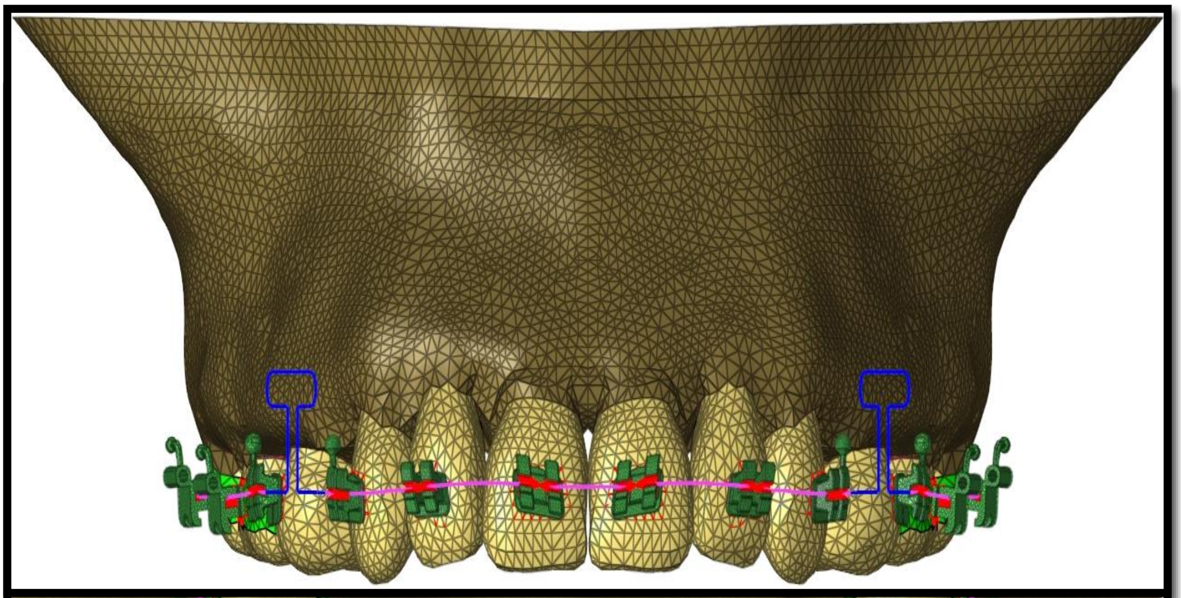

Figure 10 (a)FEM Model Conventional T Loop(Bone geometry)

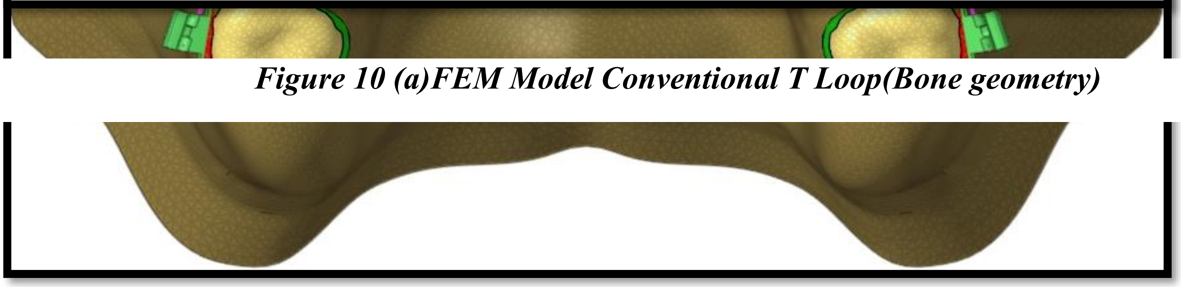

Figure 10(b) FEM Model Conventional T Loop

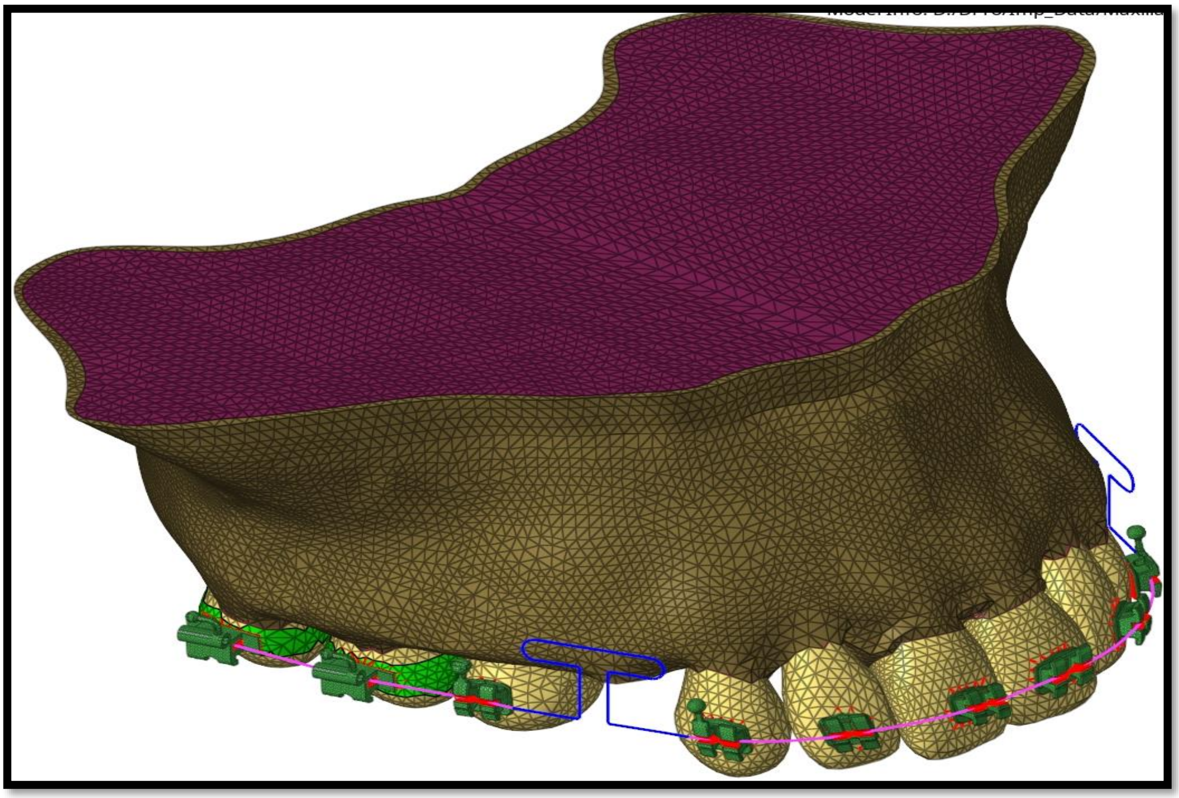

Figure 10(c) FEM Model Conventional T Loop

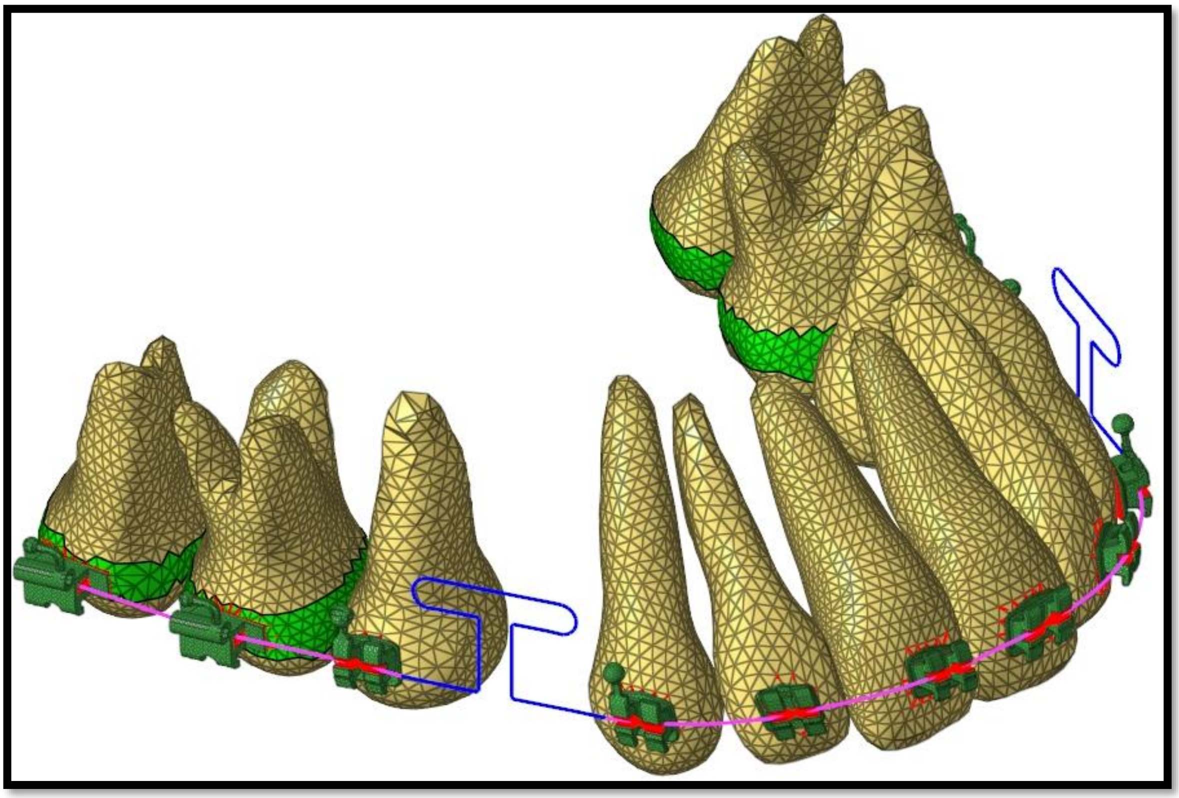

Figure 10(d)FEM Model Conventional T Loop (dental geometry)

4. **Material property data representation: material properties were assigned.**
   Material properties of the teeth, periodontal ligament, and surrounding bone were assigned based on previous studies[20]
5. **Defining the boundary condition.**
   Physical boundary conditions were then applied to the model, including loading, constraints, and other environmental factors to prevent it from free body motion.
6. **Application of force for different activations of the loop.**
   Force levels for three different activations and materials for both types of loops were analyzed using ANSYS software. The force values for both loops were evaluated at activation levels of 1 mm, 2 mm, and 3 mm.
7. **Evaluation of load deflection of the loops and force exerted.**
   Stresses (N/mm2) are calculated and presented as different colors, representing various stress levels. The red color column of the spectrum indicates maximum principal stresses, while subsequent colors such as orange, yellow, green, and blue indicate decreasing levels of stress, with blue representing the lowest level of stress. In the study, retraction forces are applied between canines and first premolars, The evaluation of stress distribution and deformation along the periodontal ligament and the surrounding bone for both loops was carried out.

MATERIAL	YOUNG'MODULUS	POISSON'RATIO
CANCELLOUS BONE	1340MPa	0.3
Cortical bone	13400MPa	0.3
PDL	0.068MPa	0.45
Dentine	18600MPa	0.3
Enamel	80000MPa	0.3
Stainless steel	200,000MPa	0.29
TMA	66+1GPa	0.3

Table 1 Elastic Properties of Different Materials

component	Density(g/mm^3)	Young'modulus(GPa)	Poisson's ratio(μ)
Teeth	1.7-06	2.03+04	0.3
Periodontal ligament(PDL)	1.7-06	0.667	0.3
Alveolar bone	1.7-06	1.37+04	0.3

Table 2 Elastomeric Properties of Teeth, Pdl and Bone

Force Production Analysis

1mm Activation

At 1mm activation, the conventional T-loop produced 4.09 N of force, which is 20% more than the T-loop with helix, which generated 3.41N (Table 3). This higher force output reflects the conventional loop's greater capacity to store and release energy. A comparative graph shows (Figure 11) that the traditional loop's force line is higher at 1mm, while the helix-modified loop offers controlled force, highlighting its suitability for specific orthodontic treatments.

2mm Activation

At 2mm activation, the Conventional T-loop produces 10.23 N of force, 33% higher than the T-loop with helix of 7.67 N (Table 3). The helix enhances stiffness and stress distribution, resulting in more effective force application. A comparative graph (Figure 11) shows a steeper curve for the conventional T-loop, highlighting its inferior efficiency and precision in delivering orthodontic forces.

3mm Activation

At 3mm activation, the T-loop with helix generates 11.94 N, showing a steady increase but nearing its functional limit. The conventional T-loop produces 17.39 N, a 46% higher force, demonstrating its superior output under high stress (Table 3). A graph (Figure 11) would show the conventional loop's line higher and more curved, reflecting its exponential force increase and structural efficiency at maximum activation.

Loop Design	Reaction Force (N)			Stiffness (N/m)		
	Activation			Activation		
	1mm	2mm	3mm	1mm	2mm	3mm
T-Loop with Helix	3.41	7.67	11.94	2.71	3.03	3.14
Conventional T-loop	4.09	10.23	17.39	3.25	4.08	4.63
Difference	**0.68**	**2.56**	**5.45**	**0.54**	**1.05**	**1.49**

Table 3: Comparison table for Reaction Force and Stiffness of T loop with helix and conventional T-loop at different activations.

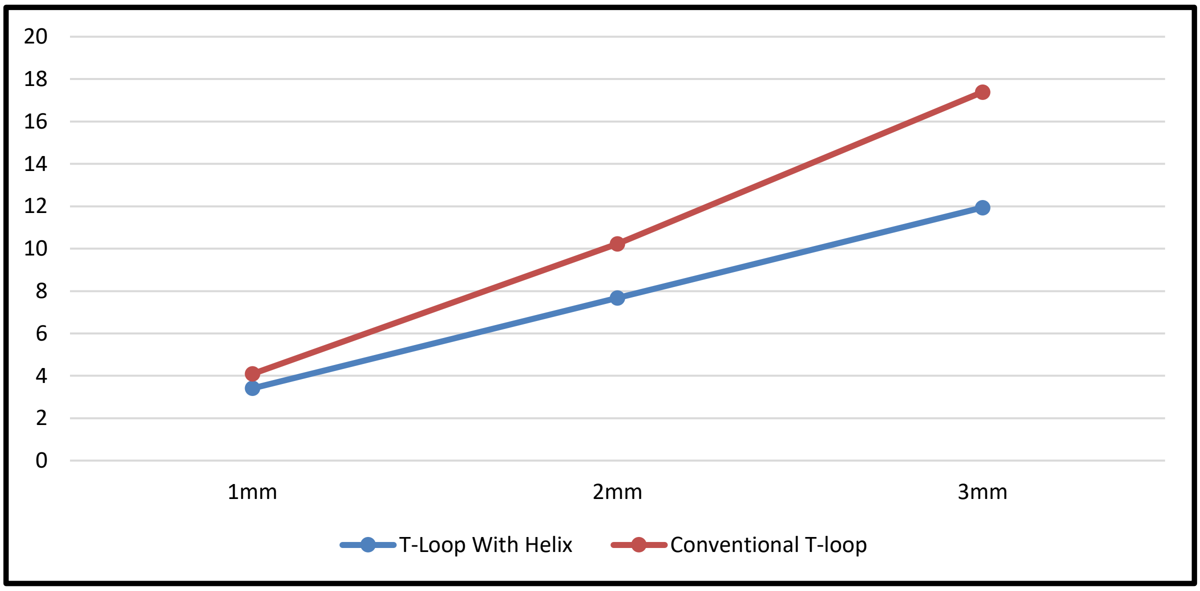

Figure 11Comparison chart for reaction force between conventional T-loop and T-loop with helix

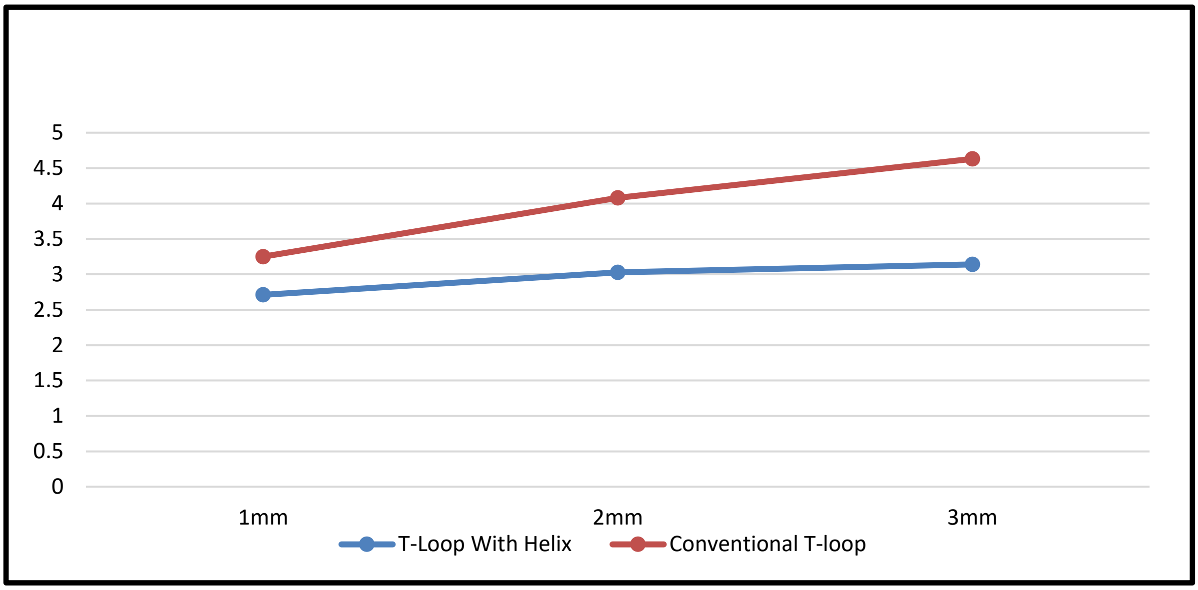

Figure 12 Comparison chart for stiffness between conventional T-loop and T-loop with helix

Stiffness Analysis

Stiffness at 1mm Activation

At 1mm activation, the T-loop with helix had a stiffness of 2.71 N/mm, offering moderate resistance to deformation. The conventional T-loop exhibited higher stiffness at 3.25 N/mm, (Table 3) indicating greater resistance and force production. The helix design alters stress distribution, reducing stiffness compared to the conventional loop. A graph would show (Figure 12) the T-loop with helix having a lower slope and the conventional T-loop with a steeper slope, reflecting their respective stiffness levels. The comparison between force reaction and stiffness is shown (Figure 12) at different activations (1mm,2mm,3mm).

Stiffness at 2mm Activation

At 2mm activation, the conventional T-loop shows a stiffness of 4.08 N/mm, with only a modest increase, suggesting it may be nearing its elastic limit. In contrast, the T-loop with helix exhibits a more substantial stiffness rise to 3.03 N/mm, (Table 3) indicating better resistance to deformation. A comparative graph (Figure 12) would show a gradual stiffness increase for the conventional T-loop and a steeper rise for the helix-modified loop, highlighting its superior performance under stress.

Stiffness at 3mm Activation

At 3mm activation, stiffness for the T-loop with helix is 3.14 N/mm, indicating a plateau where further activation adds minimal resistance. The conventional T-loop, however, shows higher stiffness at 4.63 N/mm, (Table 3) demonstrating superior structural integrity under extreme activation. A graph (Figure 12) would highlight this difference, with the helix design showing significantly less stiffness and force-maintaining capacity.

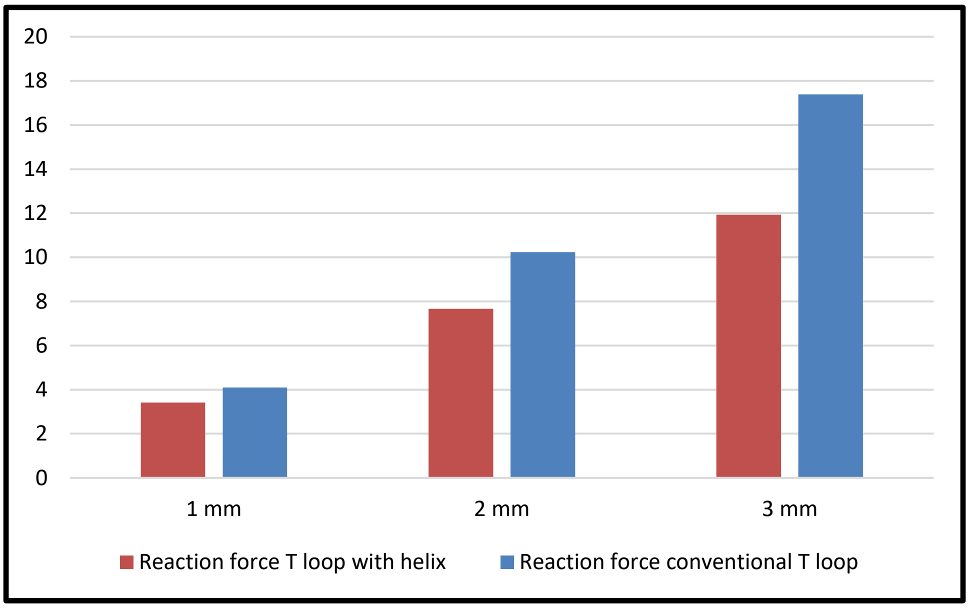

Figure 13Comparison graph for load deflection between conventional T-loop and T-loop with helix

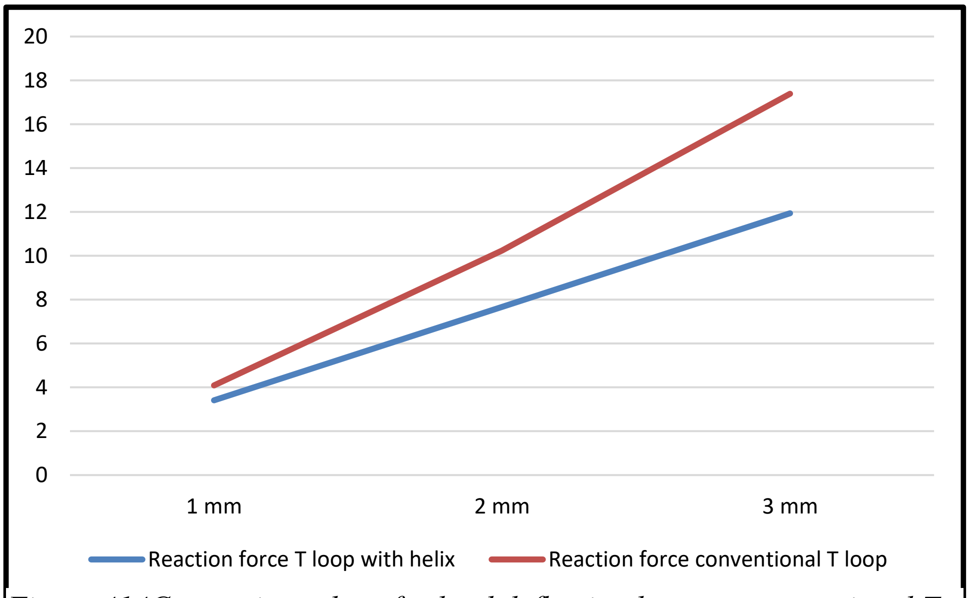

Figure 414Comparison chart for load deflection between conventional T-loop and T-loop with helix

Resultant Deflection Analysis

1mm Activation

At 1mm activation, the conventional T-loop showed moderate, uniform deflection, indicating even force distribution and predictable flexibility (Figure 13). In contrast, the T-loop with helix exhibited reduced deflection due to its stiffer design, allowing for more controlled displacement and consistent force application. This enhances precision and targeted tooth movement. A comparison graph would show the conventional T-loop with a broader arc and the helix-modified loop with a tighter, more controlled curve. comparison between

conventional T-loop and T-loop with helix shown in (Figure 14).

2mm Activation

At 2mm activation, the conventional T-loop shows significant deflection, with sharper bending near stress points, indicating it is nearing its elastic limit. In contrast, the T-loop with helix demonstrates better control, with smaller displacement increases due to stress distribution by the helices(Figure 13). A comparison graph would show the conventional loop with pronounced bending, while the helix-modified loop maintains a more uniform, controlled displacement, highlighting its precision advantage.

3mm Activation

At 3mm activation, the conventional T-loop shows substantial deflection, nearing its mechanical limit with significant bending at stress points, risking permanent deformation and

reduced force precision (Figure 13). In contrast, the T-loop with helix maintains better control, with reduced bending and consistent force distribution, staying within its elastic range. Clinically, the helix-modified loop requires less maintenance and offers more reliable performance under high forces, making it ideal for demanding treatments. A comparison graph

(Figure-14) would show the conventional loop with a pronounced curve and the helix loop with a more controlled bend.

The conclusion of result comparison between the T-loop with helix and conventional T-loop. The T-loop with helix is better than conventional T-loop.

Discussion

The helix optimizes stress distribution, enabling efficient and controlled force application. According to Siva Kumar and valiathan (2006)[30]the added helix reduces loop stiffness, allowing greater energy storage and release, resulting in stronger forces critical for significant tooth movements like a molar retraction or space closure.

Helices improve the T-loop's ability to maintain consistent force over time, crucial for gradual, controlled tooth movement without harming periodontal structures. This stability minimizes unwanted tipping or rotation, as supported by studies done by Techalertpaisarn P, Versluis A (2016)[5] and Haris et al (2018)[38]. which highlight superior force production and mechanical performance in helix-enhanced loops. The T-loop with helix, is an innovative design that improves treatment efficiency and predictability, marking a significant advancement in orthodontic biomechanics and enhancing patient results according to the Kuhlberg, A. J, & Burstone, C. J. (1997).[24]

The present study supports previous research done by Kusy et al (1986)[17] and Puente et al (1996)[22] on the conventional T-loop, reaffirming its enhanced force generation and optimized stress distribution. It supports findings, that showed that loop modifications, such as helices, enhance force control and stress distribution, optimizing orthodontic treatment outcomes.

The study also supports previous research like Bernstein et al(1971)[12] and Thiesen et al(2005)[29], on reducing root resorption risk by controlling force levels. The T-loop with helix distributes forces more evenly, minimizing high-stress points and contributing to safer, more predictable treatment outcomes, consistent with earlier findings.

While the study aligns with previous research done by Masella RS, Meister M (2006)[31], it also reveals discrepancies, particularly regarding force increase and stiffness noted only marginal force improvements, while this study found a more significant increase with the conventional T-loop, suggesting design variations may play a larger role according to Safavi et al (2006)[2].

Additionally, while the current study indicates that increased stiffness can reduce treatment time, the clinical significance may vary based on patient factors according to Jadhav et al (2023)[42]. This highlights the need for further research on the impact of helix design and individual variability in treatment outcomes.

According to Techalertpaisarn P, Versluis A (2013)[1] The T-loop with helix reduced force production, increased stress distribution, and reduced root resorption risks, confirming the benefits of helices in improving loop performance. However, discrepancies in force increase and treatment duration suggest the need for further research to explore the full potential of helices in different clinical contexts.

Analysis of Stiffness Differences

Stiffness and Stability

In a study done by Kuhlberg, A. J., & Burstone, C. J. (1997).[24] The higher stiffness of the conventional T-loop enhances stability and control, crucial for precise tooth movements. Stiffness ensures resistance to deformation, maintaining structural integrity and consistent force application during treatment. While the helix modification reduces stiffness, it stabilizes and makes force application more predictable and reliable

According to the study done by Masella RS, Meister M (2006).[31] One of the main challenges in orthodontics is managing the direction and intensity of tooth movement.The reduced stiffness of the T-loop with helix improves control by minimizing force degradation. Unlike conventional T-loops, which may lose consistency due to fatigue or flexing, the helix design maintains force application throughout treatment

The reduce stiffness of the T-loop with helix boosts stability, reducing fatigue and deformation. This lowers the need for adjustments, improving long-term efficiency according to Techalertpaisarn P, Versluis A (2016)[5]. It also minimizes discomfort, prevents unwanted tooth movements, and shortens treatment time, leading to better outcomes and higher patient satisfaction.

Deflection and Stress Distribution

In a study done by Kuhlberg, A. J, & Burstone, C. J. (1997)[24] The T-loop with helix reduces deflection by providing extra structural support, evenly distributing stress along the wire. This enhances durability and ensures more uniform force on the teeth, leading to controlled tooth movements and reducing the risk of tipping or unwanted rotations.

In comparison, a conventional T-loop shows more deflection, especially at the apex, leading to stress concentration and uneven tooth movement. The T-loop with helix has less deflection, evenly distributing stress for more consistent force, reducing discomfort and ensuring controlled, predictable tooth movement by Sivakumar A, Valiathan (2006)[30].

In a study done by Techalertpaisarn P, Versluis A (2013)[1] Excessive deflection can concentrate force on specific teeth, causing discomfort, especially during the initial treatment phase. The T-loop with helix minimizes deflection, reducing discomfort and improving patient compliance. It also helps maintain effective force, speeding up tooth movement and potentially shortening treatment time. This design leads to more controlled, predictable movements, enhancing treatment efficiency, patient comfort, and satisfaction, making it a valuable tool for orthodontists.

Stress Distribution and Periodontal Health

In a study done by Masella RS, Meister M (2006)[31] Stress distribution in orthodontic loops, like the conventional T-loop, is crucial for periodontal health. Uneven stress can cause high-pressure areas, increasing the risk of root resorption, which leads to loss of root structure, reduced tooth stability, and possible tooth loss. Which was also in seen the current study the T-loop with helix helps ensure a more even force application, reducing this risk.

In a study conducted by Kuhlberg, A. J, & Burstone, C. J. (1997)[24]the T-loop with helix improves stress distribution, reducing localized stress points and lowering the risk of periodontal issues like root resorption. The helices help spread forces evenly along the wire, enhancing tooth movement efficiency and protecting the tooth root and surrounding structures

The T-loop with helix ensures even stress distribution, protecting the periodontal ligament from inflammation and damage. This helps maintain tooth movement integrity and reduces the risk of root resorption. Additionally, optimized stress distribution supports more predictable bone remodeling, leading to smoother tooth movement, better treatment efficiency, and improved long-term dental health.

According to a study done by Faulkner et al(1989)[21]the T-loop with helix improves stress distribution, protecting periodontal health during orthodontic treatment. By minimizing localized stress, it reduces the risk of root resorption and other complications, ensuring safe and effective tooth movement. This design prioritizes both treatment efficacy and long-term periodontal health

In a study conducted by Trivedi S (2014)[6]This study highlights the biomechanical behavior of T-loops with helices and their clinical applications but acknowledges several limitations. The reliance on Finite Element Method (FEM) analysis introduces constraints, as FEM is a simplified model based on assumptions that may not fully reflect real-world clinical scenarios. Factors such as variations in material properties, patient-specific conditions, and biological responses like bone density and tissue health are not fully captured. Additionally, the study focuses on specific activation levels, limiting its applicability to a broader range of clinical situations. Practical aspects like ease of use, patient comfort, and long-term durability are also beyond its scope. While the findings provide valuable insights, further research, including clinical trials, is needed to validate and generalize these results for diverse orthodontic applications.

CONCLUSION

The following conclusion was drawn from the study. FEM study between T-loop with helix and Conventional T-loop

1. The load deflection of the T-loop with a helix decreases at activations of 1 mm, 2 mm, and 3 mm.
2. Force production at the anterior arm of the T-loop with helix is decreases at 1mm,2mm,3mm activation.
3. The load deflection in the conventional T-loop is increases at 1 mm,2mm,3mm activation.
4. The force production at the anterior arm of the conventional T-loop is increases at 1mm,2mm,3mm activation.
5. The load deflection is higher in conventional T-loop compared with T-loop with helix.

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