Evaluation and Comparison of Biomechanical Properties of Snail Loop with that of Opus Loop and Teardrop Loop for *en masse* Retraction of Anterior Teeth: FEM Study

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ABSTRACT

**Introduction:** M/F ratio, F/D rate, amount of force produced and the configuration of a loop affects the complex biomechanics involved in a translatory type of tooth/teeth movement for closure of extraction space.

**Aim:** To evaluate the biomechanical properties of snail loop and compare it with teardrop loop and opus loop.

**Materials and methods:** Finite element method analysis was carried out by utilizing Ansys10 and 11 software in a computer loaded with IBM. A total of 13 finite element models were constructed and 14 analyses were conducted in the study.

**Results:** Inherently the M/F ratio produced was higher and F/D rate produced was least for opus loop compared to snail loop and teardrop loop.

**Conclusion:** With incorporation of 20°gable bends snail loop prepared in 0.017 × 0.025 inch and 0.019 × 0.025 inch TMA wire is very efficient to deliver M/F ratio required for translatory tooth movement with acceptable F/D rate. Snail loop is easy to fabricate and finer shape morphology prevents tissue impingement.

**Keywords:** Snail loop, Opus loop, Teardrop loop, FEM.


INTRODUCTION

Space closure forms a major fraction of orthodontic treatment. Extraction space closure is carried out by retraction of anteriors or protraction of posteriors, depending upon the type of anchorage requirements. Modus operandi for closure of extraction spaces in preadjusted edgewise appliance therapy are: Friction mechanics or frictionless mechanics.

The advantage of frictionless mechanics is that there is no dissipation of force by friction. Various retraction loops, such as teardrop, opus, etc. are used as force system in frictionless mechanics. In retraction loop mechanics the only known disadvantage is that, the loop may fail to produce ideal expected results in practice due to the complexity of loop fabrication and some unknown factors. The force system of retraction loops can be tested in the laboratory and the clinician can then fabricate the spring in accordance.

The retraction loop should have an optimum size to fit into the vestibule causing no discomfort to the patient and must be easy to fabricate. For a translatory tooth movement, retraction loop should provide sufficiently high moment-to-force (M/F) ratio and low force to deflection (F/D) rate to maintain optimum force levels for a longer duration of time. Keeping these clinical considerations into mind; clinicians have proposed a variety of clinical modifications in the design of the loop, degree of bends, type, dimension and material of an archwire.

Teardrop loop is very simple to fabricate, but the inherent M/F ratio of loop is inadequate for causing translatory motion of the teeth. Opus loop design inherently produces M/F ratio close to 10:1. One major disadvantage with this retraction loop is the tissue impingement caused by it.

A blend of both the designs is seen to be integrated in snail loop. It has got design configuration similar to teardrop loop and additionally has got a helix in its design similar to opus loop. For any retraction loop to be made universally acceptable a complete knowledge of its biomechanical properties are very essential. Literature search revealed that the biomechanical efficiency of snail loop has not yet been analyzed. Present study evaluates the biomechanical efficiency of snail loop and compares it to that of teardrop loop and opus loop which are frequently used for *en masse* space closure.

**MATERIALS AND METHODS**

Mathematical approach and experimental methods are routinely used for analyzing M/F ratio and F/D rate of loop.
Evaluation and Comparison of Biomechanical Properties of Snail Loop with that of Opus Loop and Teardrop Loop


Ansys V10 and V11 finite element software was used to construct a three-dimensional model of the retraction loops after which forces and moments produced by loop geometries in all three-dimensions were studied.

A computer loaded with IBM consisting of Ansys as the pre- and postprocessor and Ansys direct solver which investigated the three-dimensional outcome of individual loops were used in the study. Based on the dimensions prescribed by the respective authors (Figs 1 to 3) a total of 13 FEM models were constructed and 14 analyses were conducted in the study.5–7

The horizontal length of all the loop models (distance between the anterior and the posterior node) were kept 13 mm considering the interbracket distance from the second premolar midpoint to the canine midpoint considering a first premolar extraction case (Figs 4 and 7).

Titanium molybdenum alloy (TMA) and stainless steel (SS) are the most commonly used wires for making loops. Most of the loop mechanics advocate full slot engagement and most often preferred wire dimension is $0.017 \times 0.025$ inch and $0.019 \times 0.025$ inch wire dimensions. Any variation in the material of wire produces a different F/D rate. Hence we chose both TMA and SS wires of both $0.017 \times 0.025$ inch and $0.019 \times 0.025$ inch wire dimensions.

Following 13 FEM models were prepared for the study:

1. Three models for snail loop were prepared in $0.017 \times 0.025$ inch TMA wire with $0^\circ$, $10^\circ$ and $20^\circ \alpha$ preactivation bends.
2. Two models for snail loop were prepared in $0.017 \times 0.025$ inch SS wire with $0^\circ$ and $10^\circ \alpha$ preactivation bend.
3. Four models for snail loop were prepared in $0.019 \times 0.025$ inch TMA wire with $0^\circ$, $5^\circ$, $10^\circ$ and $20^\circ \alpha$ preactivation bends.
4. Two models of snail loop were prepared in $0.019 \times 0.025$ inch SS wire with $0^\circ$ and $10^\circ \alpha$ preactivation bend.
5. One model each of teardrop loop and opus loop was generated in $0.019 \times 0.025$ inch TMA wire without any preactivation bends.

**Method of Analysis for Different Combinations of FEM Model**

1. **Loops without preactivation bend:** A fixed point was determined at the terminal node on the alpha side.
2. **Loops with preactivation bend**: To simulate the engagement of the wire in the brackets a rotation was added to the alpha end until the horizontal leg was completely horizontal and collinear with the bracket slot. The exact displacement at the alpha node was recorded to obtain information about the amount of cross-over produced when the wire was engaged. This point was neutral position for all the loops and starting point for all the activations. Subsequently the terminal node on the beta side was displaced by a predetermined distance after which the force and the moment produced on the terminal node on the alpha side were recorded.

**RESULTS**

Finite element analysis was carried out for different FEM models and MCSPD code was given to different models prepared, where:

- **M** represents material types (TMA or SS)
- **C** represents configurations of loops (teardrop, Tr, opus, Op and snail, Sn loops)
- **S** represents size of wire (0.017 × 0.025 inch as S1 and 0.019 × 0.025 inch as S2)
- **P** represents preactivation angle alpha (zero degree as 0°, five degrees as 5°, ten degrees as 10°, twenty degrees as 20°)
- **D** represents displacement, the amount of activation of the given loop model (1 mm as D1 and 2 mm as D2).

Total 13 FEM models were studied to evaluate the M/F ratio, F/D rate and the maximum force generated by the respective loop models after their activation.

Results of the study are tabulated as shown in Tables 1 to 3.

**DISCUSSION**

This study was designed to optimize the utilization of snail loop by understanding its biomechanical properties and also compare it with opus and teardrop loop.

It was observed that the forces, moments and F/D rate produced from SS dental archwire was nearly three times in comparison to TMA. However, the changes observed in M/F ratio was not appreciable when SS and TMA was compared (Tables 1 and 2).

When dimension of wires was changed from S1 to S2 in TMA wire a marginal increase in force produced and F/D rate was observed. In SS archwire when the dimension of wires was changed from S1 to S2 wire increase in force produced and F/D were substantial (Tables 1 and 2).

Bodily tooth movement requires production of uniform stress on PDL with a light continuous force. The inherent M/F ratio produced by snail loop is not adequate to impart translatory movement of the dentition. To increase the M/F ratio gable/preactivation bends have to be incorporated into the loop. Snail loop prepared in either TMA or SS archwire produced optimum M/F ratio for bodily movement after giving 20° α preactivation bend (Tables 1 and 2).
F/D rate produced by snail loop models prepared in TMA wire was comparatively less when compared to models prepared in SS wire (Tables 1 and 2). This observation was further substantiated in Graph 1. Reason for such an observation could be attributed to various physical properties exhibited by TMA wire.\(^1\)\(^3\) This is an important observation as loops with high F/D rate tend to deactivate faster and can exert stresses up to a level which can be traumatic to the periodontium and alveolar bone. Lower F/D ratio delivers a constant force as the tooth moves and the appliance gets deactivated late in comparison to loops producing higher F/D ratio.\(^1\)\(^3\)

For individual bodily canine retraction a force of 150 and 300 gm for anterior retraction is recommended.\(^1\)\(^4\) A force level of 70 to 120 gm is needed for bodily movement of the dentition.\(^1\)\(^5\) Force level of 100 gm is recommended for incisor retraction on each side.\(^1\)\(^6\) A force range of 320 to 350 gm for upper anteriors and 270 to 290 gm is required for lower anteriors.\(^1\)\(^7\) A force level of 200 gm for *en mass* retraction for frictional mechanics has been recommended.\(^1\)\(^8\)

Snail loop model prepared in TMA wire with dimension of S2 having 20° α preactivation bend produced maximum force of 339 gm after D2 displacement, snail loop model prepared in TMA wire with dimension of S1 having 20° α preactivation bend produced a maximum force of 328.3 gm after D2 displacement. These loop models provided ideal force levels with acceptable M/F ratio. Forces produced by models prepared in stainless steel were very high (Tables 1 and 2).

TMA wires delivered more constant moments throughout the range of deflection and thus the center of rotation of the dentition was kept constant throughout the range of tooth movement (Graph 2). Several factors related both to the thermo-mechanical processing of the wire and the larger elastic range, which requires a different bending technique, could justify this finding.\(^1\)\(^3\) Hence, TMA loops are more preferable due to their larger range and more consistent force delivery.

Comparison between snail, teardrop and opus loop prepared in S2 dimension in TMA wire without giving any preactivation bend at D1 displacement showed that M/F ratio of opus loop was 9.8 mm, teardrop loop was 4.5 mm and for snail loop was 5.5 mm (Table 3). The M/F ratio produced by all the loop models was constant throughout the period of activation (Graph 3).

Thus, we can observe that inherently opus loop produces an ideal M/F ratio required for bodily translation of the dentition. The height of the opus loop being more as compared with that of teardrop and snail loops.
to the other two loops contributes to the increase observed in the M/F ratio. This increased height of the opus loop can create problem of tissue impingement and reduce patient compliance.

F/D rate and maximum force generated of opus loop is the lowest compared to other two loops (Table 3). Configuration of the opus loop and 70° angulation given to its vertical leg during optimization of the design could be attributed to such an observation.

**CONCLUSION**

Thus after evaluating and comparing all the characteristics of teardrop loop, opus loop and snail loop we conclude that snail...
loop has a definite advantage over teardrop loop in all respects of biomechanical characters.

Snail loop with incorporation of gable bends is very efficient to deliver M/F ratio similar to that of opus loop. Finer shape morphology of snail loop provides ease of fabrication and prevents tissue impingement which is a drawback of opus loop.

For optimum utilization of snail loop it must be prepared in either 0.017 × 0.025 inch or 0.019 × 0.025 inch TMA wire and must be activated by 2 mm.

No matter how precise we try to conduct our study we cannot specifically simulate and construct an artificial oral environment to conduct a study. Hence, a further assessment on the clinical efficiency and ease of use of snail loop on patients has to be conducted.

REFERENCES