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Mechanical Behavior of A Orthodontic Retraction Loop : A Analytical And Experimental Study

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ABSTRACT

The purpose of this study was to evaluate the use of computer simulation to predict the force obtained after the activation of teardrop loops of 3 heights. Six retraction loops having cross section(16x22) were divided into 3 groups according to loop height (6, 7, and 8 mm). The loops were subjected to tensile load through displacements of 0.5, 1.0, 1.5 and the resulting forces were recorded. The loops were performed using reverse engineering and Pro E software and finite element analysis was performed with Ansys software(12.0 version).The correlation test and the paired t test ($P < .05$) were used to compare the computer simulation with the mechanical experiment. The computer simulation accurately predicted the experimentally determined mechanical behavior of teardrop loops of different heights and should be considered an alternative for designing orthodontic appliances before treatment.

Keywords : Orthodontics teardrop loop, Ansys, Pro-E, SPSS

1. INTRODUCTION:

An important aspect of orthodontic treatment is to understand tooth movement in response to mechanical loads and the associated adjacent tissue response at both clinical and histological levels. To move teeth in a controlled fashion, correct mechanical principles and an ideal orthodontic appliance must include adaptation of the device to the various types of malocclusion to better align the teeth to be moved and ease of placement in the mouth. Closure of extraction spaces is a major challenge in orthodontics as it requires the application of a specific force system. Any half hearted, indefinite, quick draw mechanics used to retract the anterior to close these spaces has resulted in failure of the attempt, relapse and disastrous post treatment occlusion. Innumerable choices are available for this step in orthodontic treatment and most of them are based on sound biomechanical principles. However, in many instances, the designs have simply evolved and were not analyzed to determine whether they would be able to provide the correct force system. It is imperative to choose one among these only on the basis of our sound understanding of the knowhow of bio mechanics. Design alterations can be made or orthodontic appliances combined to better tailor the ability to direct and distribute the mechanical forces for tooth movement. The addition of helices or changes in alloy composition and processing are commonly used to allow clinicians to more accurately achieve desired forces for tooth movement in various clinical scenarios Therefore, accurate prediction of mechanical behavior as a function of shape and material properties is necessary in clinical practice. In medicine, finite element analysis (FEA) has been mainly applied in orthopedic research for the evaluation of mechanical responses of bony structures to applied external forces. This method is particularly useful when several forces are applied to objects of complex shape and varied material properties. This method is based on the separation of the analysis shape into sub domains through finite elements. This separation allows a point analysis of the physical behavior of the object under varied loading conditions. The purpose of this study was to evaluate computer simulation to predict the force and the torsion obtained after activation of teardrop loops of 3 heights.

MATERIAL AND METHODS

Six teardrop retraction loops of TMA, 0.016 X 0.022-in rectan-

gular wire were bent and divided into 3 groups based on the height of the loops. The same operator (M.E.R.C.) prepared the specimens using a template and a light wire pliers with medium tips. After loop production, the wires were then subjected to a tensile load on the testing machine. A load cell of 20.0 N was used. For this purpose, 1 end of the specimen was fixed on the machine, and the other was displaced. Special care was taken to avoid torque incorporation while the loop was connected to the testing machine. The loops were subjected to activation steps of 0.5 mm to a maximum displacement of 2.0 mm at 1.0 mm per minute. The forces and the angle variations were measured at each of the 4 steps. Fig 1 shows the experimental setup.



Fig.3.1 Experimental setup

For computer simulation, the different loop models were created in ProE reverse engineering extension and finite element analysis performed on Ansys (version 12.0; Swanson Analysis System, Canonsburg, Pa). According to the characteristics of the teardrop loop structures and also considering the specific movements imposed by the intended mechanical ac-

tivation, solid187 elements were used for the teardrop model. This (finite) a higher order 3-D, 10-node element can respond to tension, compression, traction, and torsion movements. The SOLID187 element has 3 df, i.e. 3 translation around the axis. The modulus of elasticity of the orthodontic wire used in the FEA analysis of the springs was 96000Pa with a Poisson coefficient of 0.36. The teardrop loops were separated into finite elements, and an average of 1406 elements was used for modeling the various heights. To simulate the activation in orthodontic practice (and on pulling experiments), the 6 df were constrained in an extremity of the structure, and displacements of 0.5, 1.0, 1.5, structures and materials used in the simulation were considered isotropic and homogeneous, and with a static linear behavior. Output data were analyzed with the von Misses failure criterion A correlation test was used to compare the computer simulation with the mechanical experiment. Paired t tests at the 95% level of significance were used to determine significant differences between simulation and mechanical testing groups.

RESULTS

The mechanical testing results are given in Tables 1 and the experimentally determined forces for the 3 types of teardrop loops are shown in Figures 2. A representative displacement with computer simulation during 0.5-mm teardrop loop activation is shown in Figure 3. The forces over the x-axis and the z-axis were null.

The resulting forces for each of the 3displacements were generated by using the von Misses criterion. The mechanical and computer simulation results were compared and had a correlation coefficient of (0.987). Paired t tests showed no significant differences (P >.08) between experimental and computer simulation results.

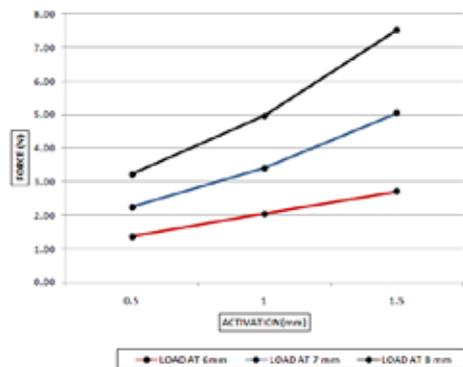


Fig 2: Mechanical Testing Result:
Here are experimental results in tabulated form.

Table 1: Experimental Results

ACTIVATION (mm)	LOAD AT 6mm	LOAD AT 7mm	LOAD AT 8mm
For 0 deg angulation			
0.5	1.37	0.88	0.98
1	2.05	1.35	1.56
1.5	2.72	2.33	2.48
For A20 deg angulation			
0.5	1.47	1.29	0.98
1	2.05	1.89	1.72
1.5	2.75	2.43	1.98
For P20 deg angulation			
0.5	1.47	1.72	1.26
1	2.18	2.46	1.66
1.5	3.03	3.14	2.05

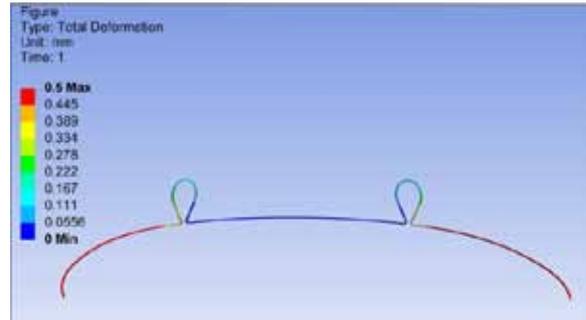


Fig 3: Computer simulation illustration of the application of displacement (act 0.5 mm) in the y axis direction

There are some graphical comparison between forces for different loop height and three different angulations i.e. 0deg,P20deg & A20deg. Fig 4:shows graphical comparison for loop height and fig 5:shows for angulation.

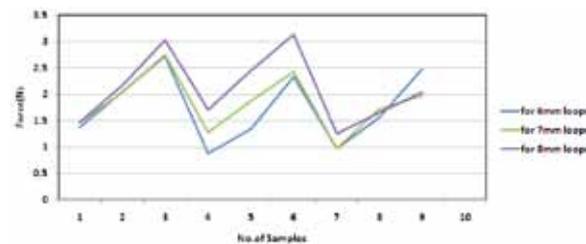


Fig 3:Graphical comparison of results for loop height.

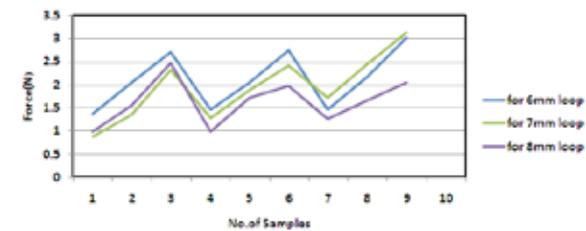


Fig 4:Graphical comparison of results for angulation

A high correlation coefficient (0.978) was found between mechanical testing and simulation. The paired t (P< 0.07) test confirmed this correlation, showing no significant differences between experimental and simulation results.

DISCUSSION:

Knowledge of the mechanical behavior of an orthodontic appliance is important to allow its correct assembly and use, and increase its efficiency for good clinical outcomes. Such Knowledge also prevents its use in areas where the results might be unsatisfactory. Biomechanical knowledge of orthodontic appliances allows better treatments and accuracy in dental movements.

After mechanical testing, the 6-mm teardrop loop had the highest force results at all activation levels. This loop also showed proportional behavior regarding the force obtained and the activation displacement. The correct loop height is proportional to the patient's anatomic limitation. When possible, loop that release low force levels are preferred. The ideal force applied to achieve movement of the mandibular incisors is approximately 2.60 N. The springs that best approached this value were the teardrop springs of 6-mm height activated 1.5 mm, which provided 2.62 N force, and the teardrop loop of 8-mm height activated 1.5 mm, which provided a 2.48 N force. The teardrop loops with heights of 7 and 8 mm activated 0.5 mm had values less than 2.60 N: 1.89 and 1.37 N, respectively.

The teardrop loops with heights of 7 and 8 mm activated 1.0, 1.5, and 2.0 mm had higher forces than the ideal values for

mandibular incisor movement. For the maxillary incisors, the ideal force level is 3.10 N. When activated 1.0 mm, the teardrop loops with heights of 7 and 8 mm induced forces that were close to the ideal levels: 3.43 and 2.77 N, respectively. Activations greater than 1.0 mm showed forces that were higher than the ideal value for all springs tested.

A high correlation coefficient (0.978) was found between mechanical testing and simulation. The paired t ($P < 0.07$) test confirmed this correlation, showing no significant differences between experimental and simulation results.

Computer simulations are now widely available because of significant decreases in costs associated with increased computation power capability. Additionally, computer simulation software has gained interfaces that are more users friendly and, thus, has become more popular recently. These 2 factors might result in the development of customized software for orthodontic applications and the choice of appliances used in clinical practice.

CONCLUSION

A high correlation coefficient (0.978) was found between mechanical testing and simulation. The paired t ($P < 0.07$) test confirmed this correlation, showing no significant differences between experimental and simulation results

The computer simulation accurately predicted the experimentally determined mechanical behavior of teardrop loops of several heights and should be considered an alternative for designing orthodontic appliances before treatment.

This study also gives a very analytical picture of what happens with each design with different loop heights and different angulations and different material. We observed that resulting force for TMA material had values close to the ideal values for mandibular incisor and the maxillary incisors movement so we can say that the TMA material is best choice for orthodontic loop.

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