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ORIGINAL ARTICLE

# Evaluation of Force Decay of Elastomeric Ligatures in Simulated Oral Environment

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## ABSTRACT

**Aim:** The aim is to assess the amount of force decay of the elastomeric ligatures at a constant distance at different time intervals in a simulated oral environment.

**Materials and methods:** The elastomeric ligatures were obtained from 3M Unitek. Totally, 100 elastomeric ligatures obtained were stretched to twice their outer diameter to study the force degradation pattern under static conditions over a period of 6 weeks in a simulated oral environment. The values obtained were statistically analyzed using repeated measures analysis of variance (ANOVA).

**Results:** Elastomeric ligatures exhibited significantly high initial force levels. There was a rapid force loss for all the ligatures after day 1, followed by week 1. However, they exerted more consistent force levels in the 2nd, 3rd, and 4th weeks, exhibiting a minimal force decay of 6% in 2nd to 4th weeks.

**Conclusion:** Elastomeric ligatures exert clinically significant force levels over a period of 4 weeks necessary for tooth movement. A monthly activation schedule is recommended.


**Keywords:** Decay, Elastomeric ligatures, Force.

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**Conflict of interest:** None

## INTRODUCTION

Tooth movement is the essence of orthodontic treatment. During orthodontic tooth movement, light and continuous forces are desirable for optimum tissue response and rapid tooth movement.[1]

The ability to close space efficiently in orthodontic tooth movement is of major clinical importance and depends on the force system employed.

The ideal space-closure system should have mechanical properties that provide a continuous light force, preserve periodontal integrity, and close the space with minimum time. Forces needed to achieve space closure can be obtained by a number of techniques, including coil and retraction springs, closing loop arch wires, magnets, and elastomeric chains.[2]

Elastics and elastic chains used traditionally in orthodontics in the form of ligatures and chains or modules are chemically polyurethane elastomers.[3]

Numerous studies have been conducted to evaluate their strength in terms of force delivery and rate of force decay in various environments and different testing conditions.[4-8] Factors, such as tooth movement, temperature changes, pH variations, oral fluoride rinses, salivary enzymes, and masticatory forces have all been associated with the deformation, force degradation, and relaxation behavior of these elastomers. It has been found that a force loss of about 50 to 70% occurs in the first 24 hours followed by a steady decline over the next 3 to 4 weeks.[9]

The MBT philosophy introduced the concept of using elastomeric ligatures in the form of active tiebacks to apply a force of 150 to 200 gm for *en masse* retraction of anteriors with sliding mechanics.[10]

Since sliding mechanics have been widely employed to close residual extraction spaces using elastomeric ligatures, it is important to compare the force exerted by commonly used brands of such ligatures.

To date, there is no study to evaluate force degradation of elastomeric ligatures in the form of active tiebacks. Hence, the present study was designed to evaluate the force degradation of elastomeric ligatures over a 6-week period under static conditions in a simulated oral environment.

## MATERIALS AND METHODS

Orthodontic elastomeric ligatures were obtained from 3M Unitek. About 100 samples were obtained and stretched to twice their outer diameter to study the force degradation over a period of 6 weeks.

Each elastomeric ligature was stretched by twice its outer diameter as recommended by the MBT system.[10,11]

A custom-made model (Fig. 1) was designed with 20 pins on either side of the length of the model. All the pins were equidistant from each other, so the extension was similar and kept constant throughout the study for all the elastomeric ligatures with minimum error. Then, from the outer edge of the pin, a measurement of 6 mm

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**Fig. 1:** Ligatures stretched on the model for the study

**Fig. 2:** Correx gauge being used for measuring force levels

was made on the model using a digital Vernier caliper to mark the desired amount of stretching required for the elastomeric ligatures. Five elastomeric ligatures were stretched on each pin resulting in a total of 100 elastomeric ligatures, which were then immersed in artificial saliva (pH = 7–7.4) and incubated in an incubator maintained at 37°C to simulate the oral environment.

After incubation, the force levels were measured using a Correx gauge (Fig. 2) at the following intervals: initial, 1 hour, 24 hours, 1 week, 2 weeks, and each subsequent week until 6 weeks to study force degradation.

During the experiment, factors, such as temperature of artificial saliva, time in solution, and deformation during handling on the model were kept as consistent as possible.

### Statistical Analysis

All the data were analyzed using Statistical Package for the Social Sciences software version 16 (SPSS Inc; Chicago, Illinois, USA). Results were presented as mean ± standard deviation. For the statistical analysis, repeated measures ANOVA was used to make comparison in intragroup measurements.

## RESULTS

Tables 1 and 2 show the results for the force levels and force degradation using descriptive statistical analyses, including means and standard deviations at different time intervals.

The elastomeric modules displayed 389 gm at initial level and degraded to 85 gm at the end of 6 weeks (Table 1).

There was statistically significant degradation of force from the initial to the end of the experimental period (Graph 1).

**Table 1:** Mean, standard deviation, and level of significance for force levels of 3M Unitek

| | *3M* | |
|---|---|---|
| *Intervals* | *Force levels (in gm)* | *p-value** |
| Initial | 389.05 ± 32.714 | 0.000** |
| 1 hour | 275.24 ± 28.321 | 0.000** |
| 1 day | 229.24 ± 25.370 | 0.000** |
| 1 week | 168.10 ± 16.589 | 0.000** |
| 2 weeks | 143.14 ± 16.250 | 0.000** |
| 3 weeks | 132.95 ± 18.130 | 0.000** |
| 4 weeks | 116.86 ± 16.072 | 0.000** |
| 5 weeks | 102.10 ± 16.507 | 0.000** |
| 6 weeks | 85.43 ± 17.706 | 0.000** |

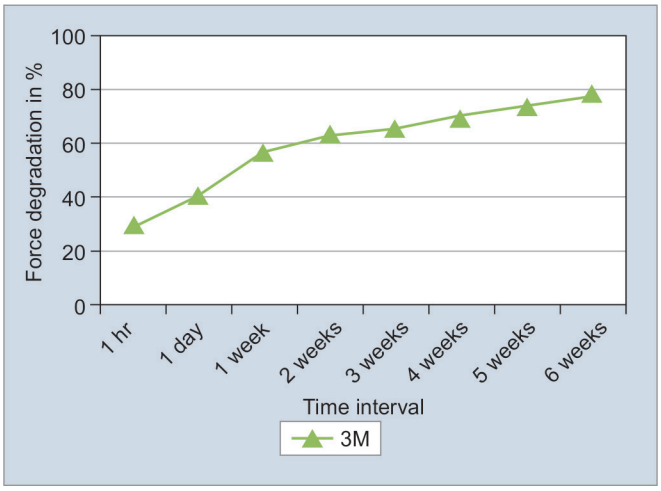
*p ≤ 0.05 indicates the parameter is significant; **p ≤ 0.001 indicates the parameter is highly significant

**Table 2:** Percentage of force degradation

| *Intervals* | *Force degradation (in percentage)* |
|---|---|
| 1 hour | 29.3 |
| 1 day | 40.9 |
| 1 week | 56.8 |
| 2 weeks | 63.2 |
| 3 weeks | 65.8 |
| 4 weeks | 69.9 |
| 5 weeks | 73.8 |
| 6 weeks | 77.9 |

## DISCUSSION

The optimal force magnitude required to close spaces orthodontically is controversial.[12] Although the force is dependent on the root surface area of the tooth to be moved, the force magnitudes required to bodily move canines are estimated to range from as low as 100 gm to as high as 300 or 350 gm. If, during treatment, forces fall below approximately 55 gm, bodily movement of the canines essentially ceases.[2] At initial placement, elastomeric chains can deliver




**Graph 1:** Line diagram representing percentage of force degradation pattern for part I

sufficient force to move the teeth. Unfortunately, the force decays over time. The degree of degradation could result in forces that fall below the threshold value, precluding any therapeutic effect.

Currently, the most common method used by orthodontists to close extraction space is by employing sliding mechanics popularized by the MBT philosophy. Using forces as low as 200 gm for *en masse* retraction of six anteriors, the elastomeric ligatures have become popular means of applying required retraction force in the form of active tiebacks.[10,11]

The elastomeric ligatures displayed very high initial forces (Table 1). These forces are well above the required physiologic force recommended of 200 gm, for retraction.

The optimal force level recommended by McLaughlin is 150 to 200 gm for *en masse* retraction of six anteriors. In the present study, after the first day to the third week, the force levels fall roughly near this range and may be considered to be acceptable. The force levels in the 4th, 5th, and 6th weeks fall short of the ideal requirement. However, there is only a 4% degradation of force in the 4th week. This may not have much clinical significance and would justify the 4-weekly activation currently followed and considered convenient in day-to-day clinical practice. The force levels in the 5th and 6th weeks fall in the range of 100 gm and below which may be insufficient to bring about tooth movement. Canine retraction ceases when force levels drop below 50 gm.[2] Hence, it may be concluded that the elastomeric modules from 3M Unitek are adequate for use as active tiebacks in sliding mechanics for *en masse* retraction of six anteriors at 4-weekly activation.

Huget et al[13] found that ligatures exposed to moisture first leads to weakening of noncovalent forces and then degradation of the ligature. Exposure of elastomeric chains to a test solution (pH 7.26) significantly produced more force decay than an acidic solution.[14] Many authors have reported permanent deformation and rapid force loss of these products. These products lose 50 to 70% of their force in the first 24 hours.

Taloumis et al[15] did a study to evaluate the force degradation of the elastomeric ligatures and found that they exhibit a rapid force loss of 53 to 68% in 24 hours, in contrast to our study where we found a force decay of 41% after 24 hours. The clinical relevance of this study is that, most commercially available elastomeric ligatures exhibit excessive initial forces. There was rapid force degradation after day 1 of 41%, followed by 57% of force degradation at the end of 1 week. However, a more consistent force was seen in the 2nd, 3rd, and 4th weeks exhibiting minimal force decay.

All commercially available elastomeric ligatures look similar and, hence, it is difficult for the clinician to judge force levels and force decay of each brand and company. Hence, it may be recommended that it is advisable to use elastomeric ligatures of those companies that tend to supply more standardized materials.

Based on the force levels of elastomeric ligatures, the present study recommends a 4-week activation schedule so as to retain physiologic tooth-moving forces in the system.

It would be advisable to examine all available elastomeric ligatures so the clinician can make an informed choice.

One of the limitations of this study is that the effects of temperature changes were not studied. Also, the effects of masticatory forces were not considered. The effect of bacteria and bacterial products was not taken into consideration. In clinical conditions, tooth movement occurs, which was not taken into consideration. These could be included in further extensions of this study to get a more precise interpretation of the clinical situation. However, considering the lacuna in the evidence, regarding force levels of elastomeric ligatures, for retraction in the form of active tiebacks, this study gives valid information on the force magnitude of 3M Unitek elastomeric ligatures during treatment.

## CONCLUSION

From the present study, the following can be concluded:

- Elastomeric ligatures exert excessive initial force levels well above the optimal recommended force levels.
- Elastomeric ligatures lose considerable force at the end of day 1 and at the end of the 1st week, with the maximum loss occurring in the first hour.
- From the 2nd to the 4th week, minimal force degradation occurs.
- Based on the force levels exerted, the present study recommends a 4-week activation schedule of elastomeric ligatures for forces to fall within the optimal range required for tooth movement.

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