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Original Research Article

Time-dependent force depreciation of intraoral orthodontic elastics of variable force and lumen sizes – An in vitro study

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ABSTRACT

Objective: To evaluate force decay of elastics of different dimensions and different force values over 48-hours.
Materials and Methods : Steps included extension and immersion of elastics in artificial saliva and measurement of force levels at a specified point of time. A model with vertical pins placed at in the oral cavity. The initial force measurement was done using Universal testing machine before the elastics were engaged onto the pins 37°C in artificial saliva. The reading was taken after this in the Universal testing machine for the samples. The elastics were then placed back into the static simulation for the next 23 hours and again into the dynamic simulation for the next 1 hour.
Results: Statistically significant difference ($P<0.05$) was observed between force depreciation between rest and maximum stretch of the elastic. Statistically significant difference was observed in force depreciation with varying time intervals of a particular elastic sample. Lumen size and pre-determined force values affect the overall force decrease pattern of elastics.
Conclusion: Elastics with higher force and smaller lumen size show comparatively higher loss of force than the lighter elastics with larger internal diameter. The maximum force loss of a particular elastic happens within the first 24 hours of elastic stretch.
Clinical Significance: The study would help provide information about how an elastic's lumen size and initial force are interdependent, giving clinicians a better understanding of how to prescribe the right elastics for the force they need to apply for treatment.

1. Introduction

Mechanotherapy in orthodontics often involves the use of interarch latex elastics to correct sagittal discrepancies or improve the interdigitation of teeth. Whereas these auxiliaries are replaced daily, a concern associated with their use pertains to the force relaxation of the materials.[1] Elastics used in Orthhigh flexibility and relatively enduring force.[2] A light contfor orthodontic tooth movement and minimal patient discomfort. Elastics are usually used forces to increase or supplement the force provided by the arch wire.[3] Proffit et al. listed 2 ideal forces for elastics depending on the size of the wire. When using large rectangular wire, he suggested approximately using 250 g force for inter arch correction and force levels of 125 g for lighter round wires.[4]

Elastics are used to achieve orthodontic tooth movement like tooth retraction, space closure, cross-bite correction

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or inter-maxillary traction.[5] When placed in the mouth, elastics are not subjected to static forces alone.[6]

Intermaxillary tension of elastics varies with the distance during jaw movement.[7] given for patient talks, eats, The loss of force delivery and degradation of orthodontic elastics affect their clinical effectiveness.[8] In inconstant force expression with considerable maintain the required force.[3] It has been a common finding that rubber elastics in a watery or oral environment lose between 10% and 40% of their initial force between 30 minutes and 24 hours after they are applied.[7]

Mechanical degradation effects are considered to be the primary cause for degradation of orthodontic elastics when in use.[3] Many studies have shown a high force decay rate having 2 slopes: initial rapid force relaxation and latent decay of decreased slope. Orthodontic rubber elastics are supplied based on standard force index. This means if the elastic is stretched to 3 times the listed diameter, it will exert a tensile force approximately equal to the listed force.[7] Force gauges have been used traditionally to evaluate the force decay shown by the orthodontic elastics.[5]

A recent study in 2018 compared force degradation of non-latex and latex elastics over a duration of 48 hours. They reported that both showed similar trends of degradation however latex showed insignificant reduction in 12-48 hours while for non-latex this occurred during 28-48 hours.[2,9]

This study aimed to compare latex elastics depending upon the initial force and lumen size over the period of 48 hour show an elastic's lumen size and initial force are interdependent, giving clinicians a better understanding of how to prescribe the right elastics for the force they need to apply for treatment.

2. Aim and Objectives

This study aimsanalyze the rate of force degradation of orthodontic elastics of different force levels and lumen sizes in a simulated static and dynamic oral condition over a period of 24 hours and 48 hours respectively

3. Clinical Significance

The loss of force delivery and degradation of orthodontic elastics are major defects that affect clinical choice. This m akes it difficult for the clinician to determine the actual force applied to the dentition. Clinicians, hence, should be aware of the forces applied to the teeth when elastics are applied to the: lentition at a given elastic extension and how the force declines over time.

4. Materials and Methods

The study was conducted in the Department of Orthodontics and Centre for Advanced Research at a Dental College & Hospital in Ghaziabad. Ethical clearance was obtained from Institutional Ethical Committee (IIEC/RP/2021/002).

Steps included extension and immersion of elastics in artificial saliva and measurement of force levels at a specified point of time. Vertical pins were used for the purpose of simulating the various distances in the oral cavity. The first pair of vertical metal pins was placed in a cold cure resin plate and at a distance of 25mm to simulate the distance of molar and canine in the rest position in the oral cavity. Second pair of vertical pins was inserted in the resin at the distance of 40 mm to simulate the maximum occlusal distance in the oral cavity.

The initial force measurement was done using Universal testing machine before the elastics were engaged onto the pins. The person measuring was blinded to the knowledge of groups and subgroups to avoid any bias. The elastics of each sub-group were stretched and placed onto the static oral conditions for 23 hours and the second set of pins for dynamic oral simulation for one hour (corresponding with 20 minutes per meal in a day).

The entire acrylic plate was immersed into the glass container containing artificial saliva (ICPA mouth rinse) and then the entire assembly was placed into a water bath with the temperature maintained at 37°c to simulate normal oral cavity temperature.

The reading was taken after this in the Universal testing machine for the samples. The elastics were then placed back into the static simulation for the next 23 hours and again into the dynamic simulation for the next 1 hour. The reading was again taken after this and the comparison was made among the force levels. (Table 1) (Figure 1)

The readings per subgroup was recorded for the following time intervals:

1. T0 - At time zero.
2. T1- after 24 hours (23 hours of 25mm stretch and 1 hour of 40 mm stretch).
3. T2- after 48 hours (next 23 hours of 25mm stretch and 1 hour of 40 mm stretch) Readings were standardized in Gram milli force (GmF).

5. Results

Intergroup comparison was carried out by ANOVA test and Post hoc Bonferroni test with $P \leq 0.05$ indicated significant difference. The force values between the maximum and rest range within groups were compared using independent 't' test. The tables show the comparison within group between forces at rest extension and maximum extension of the same samples over a period of 48 hours. It showed that the same elastic sample has different force levels depending on the length of extension i.e. more will be the extension of the elastic, more will be the force applied by it. Maximum force depreciation seen in the group B3 at maximum extension. (Tables 2, 3, 4 and 5)

In this study, the first group consisted of 3 subgroups. Group with 3.5 Oz force and 3/8" lumen showed 12% loss in 24 hours and 13% in 48 hours at simulated rest distance and 12% in 24 hours and 16% in 48 hours for maximum extension.

Group with 3.5 Oz force and 5/16" lumen showed 3% force loss at 24 hours and 9% loss at 48 hours at rest and 2% at 24 hours and 8% at 48 hours for maximum extension. Group with 3.5Oz force and 3/16" lumen size showed 18.6% force loss at 24 hours and 19% loss at 48 hours at rest and 29.3% force loss at 24 hours and 31.3% force at 48 hours at maximum extension.

The second group consisted of 3 subgroups. Group with 4.5Oz force and 3/16" lumen size showed 5.7% force loss at first 24 hours and 16% after 48 hours at rest and 15% at 24 hours and 29% 48 hours at maximum extension. Group with 3.5Oz force and 3/16" lumen showed 9% loss at 24 hours and 14% 48 hours at rest extension and 18% force loss at 24 hours and 25% force loss at 48 hours at maximum extension.

Table 1: Group-wise sample allotment

Group	Subgroup 1	Subgroup 2	Subgroup 3
Group A (constant force)	3.5 oz – 3/8" lumen	3.5 oz – 5/16" lumen	3.5 oz – 3/16" lumen
Group B (constant lumen size)	4.5 oz – 3/16" lumen	3.5 oz – 3/16" lumen	6 oz – 3/16 " lumen

Figure 1: Testing of the elastics in universal testing machine

6. Discussion

Although an in-vitro testing is unable to represent actual clinical applications, This study's test results aid in providing ideas of interrelation of elastic force and lumen size. This also provides guidelines for choosing elastics for clinical use.

It was observed in this study that the elastics with a smaller lumen size, even if the force was kept constant showed more force degradation compared to other larger lumen sizes (3/16"> 5/16"> 3/8") and maximum loss was seen in first 24 hours. When the lumen sizes were kept constant, the maximum force reduction was seen in the group with maximum inherent force levels which was 6oz force with 3/16" lumen size.

Dynamic extension showed more loss of force compared to the static extension indicating the length of extension is one of the factors that affect the force loss. This result is similar to most of the studies in literature.[1,4]

Group with 6Oz force and 3/16" lumen showed 12.5% force loss at 24 hours and 17.8% at 48 hours and 18% force loss at 24 hours and 24.1% at 48 hours at maximum extension. The results of subgroup 6Oz – 3/16" and 3.5Oz – 3/16" are similar to the results of a study by kersey et al.[3] Their study also indicated that dynamic testing led to faster force decrease but was not clinically significant compared to static testing.

A study done by Bales concluded that lesser is the lumen size (higher is 3 x lumen size) more force would be generated by the elastic.[10] This result is similar to the results of present study as 3.5 Oz – 3/16" lumen has the smaller lumen size compared to other subgroups of the group A with the same initial force. Bales et al. cited Bertram in 1931 as having first reported that one third of an elastic's developed force is lost per day and further suggested that, clinically, elastics should be changed on a daily basis.[10]

Results of this study also coincides with that of Yogosawa et al that larger is the extension, more is the force loss experienced. However, this study found that the higher the force levels observed, the greater the force loss observed.[11]

Force loss percentage of 3.5Oz- 3/16" lumen at maximum extension at first 24 hours is similar to the force loss observed by Hwang and Cha.[12] There was about 4-6% more of force loss when compared from 24 hour reading to 48hour reading and this observation is supported by the study done by Wang.[13]

One of the major drawbacks of the methodology of this study, as also discussed in the literature, was the repeated testing of the same sample over different time frames which leads to additional force depreciation leading to some

Table 2: Comparison of force within group A

	Groups	T0	T1	T2	p value	Intergroup comparison
At rest	**A1**	114.25 ± 7.98	102.42 ± 8.39	99.58 ± 10.05	0.002*	T0 vs T1 = 0.039* T0 vs T2= 0.003* T1 vs T2 = 1.000
	A2	110.33 ± 8.42	106.08 ± 8.82	100.92 ± 8.76	0.024*	T0 vs T1 = 0.625 T0 vs T2= 0.011* T1 vs T2 = 0.558
	A3	204.33 ± 39.04	166.42 ± 16.85	165.58 ± 23.02	0.012*	T0 vs T1 = 0.056 T0 vs T2 = 0.042* T1 vs T2 = 1.000
		A1 vs A2 = 1.000 A1 vs A3 = 0.001* A2 vs A3 = 0.001*	A1 vs A2 = 1.000 A1 vs A3 = 0.001* A2 vs A3 = 0.001	A1 vs A2 = 1.000 A1 vs A3 = 0.001* A2 vs A3 = 0.001*		
Maximum	**A1**	155.58 ± 9.86	136.58 ± 11.04	130.75 ± 11.22	0.001*	T0 vs T1 = 0.001* T0 vs T2 = 0.001* T1 vs T2 = 0.149
	A2	149.42 ± 13.50	145.25 ± 7.62	137.67 ± 10.53	0.016*	T0 vs T1 = 1.000 T0 vs T2 = 0.025* T1 vs T2 = 0.084
	A3	399.25 ± 61.72	282.75 ± 31.73	274.42 ± 35.00	0.001*	T0 vs T1 = 0.001* T0 vs T2 = 0.001* T1 vs T2 = 1.000
		A1 vs A2 = 1.000 A1 vs A3 = 0.001* A2 vs A3 = 0.001*	A1 vs A2 = 0.881 A1 vs A3 = 0.001* A2 vs A3 = 0.001*	A1 vs A2 = 1.000 A1 vs A3 = 0.001* A2 vs A3 = 0.001*		

Repeated measure ANOVA test; * indicates significant difference at p≤0.05
Post hoc Bonferroni test; * indicates significant difference at p≤0.05

Table 3: Comparison of force within group B

	Groups	T0	T1	T2	p value	Intergroup comparison
At rest	B1	210.42 ± 14.44	198.33 ± 17.46	176.58 ± 5.07	0.001*	T0 vs T1 = 0.266 T0 vs T2 = 0.001* T1 vs T2 = 0.010*
	B2	195.42 ± 19.87	177.58 ± 13.84	166.83 ± 9.82	0.001*	T0 vs T1 = 0.069 T0 vs T2 = 0.009* T1 vs T2 = 0.083
	B3	320.75 ± 44.46	280.75 ± 25.51	263.33 ± 16.99	0.001*	T0 vs T1 = 0.013* T0 vs T2 = 0.006* T1 vs T2 = 0.128
		B1 vs B2 = 0.657 B1 vs B3 = 0.001* B2 vs B3 = 0.001*	B1 vs B2 = 0.042* B1 vs B3 = 0.001* B2 vs B3 = 0.001*	B1 vs B2 = 0.148 B1 vs B3 = 0.001* B2 vs B3 = 0.001*		
Maximum	B1	414.33 ± 30.54	351.17 ± 34.56	290.92 ± 16.33	0.001*	T0 vs T1 = 0.001* T0 vs T2 = 0.001* T1 vs T2 = 0.001*
	B2	380.75 ± 38.93	309.92 ± 43.68	284.33 ± 16.99	0.001*	T0 vs T1 = 0.002* T0 vs T2 = 0.001* T1 vs T2 = 0.173
	B3	531.25 ± 38.90	435.33 ± 32.08	403.75 ± 31.00	0.001*	T0 vs T1 = 0.001* T0 vs T2 = 0.001* T1 vs T2 = 0.005*
		B1 vs B2 = 0.091 B1 vs B3 = 0.001* B2 vs B3 = 0.001*	B1 vs B2 = 0.031* B1 vs B3 = 0.001* B2 vs B3 = 0.001*	B1 vs B2 = 1.000 B1 vs B3 = 0.001* B2 vs B3 = 0.001*		

Table 4: Comparison of force among rest and maximum within group A

	Rest	Maximum	Difference	t value	p value
T0 (A1)	114.25 ± 7.98	155.58 ± 9.86	-41.33	-11.29	0.001*
T1 (A1)	102.42 ± 8.39	136.58 ± 11.04	-34.17	-8.534	0.001*
T2 (A1)	99.58 ± 10.05	130.75 ± 11.22	-31.17	-7.168	0.001*
T0 (A2)	110.33 ± 8.42	149.42 ± 13.50	-39.08	-8.508	0.001*
T1 (A2)	106.08 ± 8.82	145.25 ± 7.62	-39.17	-11.645	0.001*
T2 (A2)	100.92 ± 8.76	137.67 ± 10.53	-36.75	-9.295	0.001*
T0 (A3)	204.33 ± 39.04	399.25 ± 61.72	-194.18	-9.245	0.001*
T1 (A3)	166.42 ± 16.85	282.75 ± 31.73	-116.33	-11.217	0.001*
T2 (A3)	165.58 ± 23.02	274.42 ± 35.00	-108.83	-9.000	0.001*

Independent t test; * indicates significant difference at $p \leq 0.05$

Table 5: Comparison of force among rest and maximum within group B

	Rest	Maximum	Difference	t value	p value
T0 (B1)	210.42 ± 14.44	414.33 ± 30.54	-203.92	-20.912	0.001*
T1 (B1)	198.33 ± 17.46	351.17 ± 34.56	-152.83	-13.673	0.001*
T2 (B1)	176.58 ± 5.07	290.92 ± 16.33	-114.33	-23.164	0.001*
T0 (B2)	195.42 ± 19.87	380.75 ± 38.93	-185.33	-14.689	0.001*
T1 (B2)	177.58 ± 13.84	309.92 ± 43.68	-132.33	-10.004	0.001*
T2 (B2)	166.83 ± 9.82	284.33 ± 16.99	-117.50	-20.741	0.001*
T0 (B3)	320.75 ± 44.46	531.25 ± 38.90	-210.50	-12.344	0.001*
T1 (B3)	280.75 ± 25.51	435.33 ± 32.08	-154.58	-13.078	0.001*
T2 (B3)	263.33 ± 16.99	403.75 ± 31.00	-140.42	-13.761	0.001*

Independent t test; * indicates significant difference at $p \leq 0.05$

change in the readings.

However, in a study done by Kanchana and Godfrey, it was mentioned that to gain a more complete and empirical understanding of the physical properties of elastic materials under clinical conditions, it would be useful to include pre stretching, thermal cycling, using artificial saliva as the immersion medium, and cyclic stretching and relaxation to simulated chewing during the use of orthodontic elastics.[7] The present study fulfils most of the above-mentioned methodology.

Timing for changing elastics is also a clinical issue as some authors suggest changing elastics every hour. In real practice, elastics are exposed to numerous intra oral factors. The mechanical properties of elastomers are influenced by the rate and duration of loading as well as environmental conditions.[14] Hence clinical decisions cannot be made on the basis of an *in-vitro* experiment. The intraoral environment exerts greater effects on the elastic. This occurs because the oral cavity includes a wide array of potent aging factors such as pH fluctuations, temperature and enzymatic and microbial action.

Kersey reported 17% force degradation at 24 hours for 20 mm with the statically stretching method.[15] Fernandes stated although water immersion and temperature are significant in the degradation of force because of interference in secondary elastics bond sites perhaps transitory hardening of material could explain the force increase.[16] Filho et al.[13]

Veeroo et al. identified barriers to compliance with recommendations concerning the wearing of elastics during orthodontic treatment and tested the use of implementation intentions to enhance compliance. They observed that barriers to wearing elastics included the discomfort associated with the elastics. Much like fixed appliances in general, the participants found that the discomfort was worse when they initially started wearing elastics.[17] This observation may be linked to the initial high value of forces present in the elastics which induce initial discomfort. As the forces degrade, the pain and discomfort felt by the patient reduces. Klabunde and Grünheid[18] evaluated the force decay over time of latex and non-latex orthodontic elastics subjected to either static or dynamic stretching under simulated intraoral conditions and found that latex elastics retained significantly more force over time than their non-latex equivalents. Because of the higher force decay in a dynamic environment, it is important that non-latex elastics be changed more frequently. These findings are similar to the ones we found in our study.

The method in the present study also suffered from another major weakness: it failed to allow for the collection of continuous data because the force was only periodically recorded; thus, non-continuous data were used to construct the force relaxation curves, inducing some unavoidable approximation. Nevertheless, this limitation was in general agreement with the approach of other studies.[2,13,14]

It would be reasonable for the manufacturers to expect clinicians to use their judgment in prescribing the use of particular elastics for their patients according to force requirements to be applied at specific intraoral elastic stretch distances. Nevertheless, the clinician has to rely on reasonable constancy of working properties for any elastic type; this requires quality control in manufacturing.

7. Conclusion

The maximum force loss of a particular elastic happens within the first 24 hours of elastic stretch. The distance of extension would alter that rate of force depreciation, more would be the elastic extension, more would be the loss of force. Elastics with higher force and smaller lumen size show comparatively higher loss of force than the lighter elastics with larger internal diameter. The force levels of the elastics vary from the prescriptions provided by the manufacturer. Also, the elastic forces vary within the same lot of elastics provided by the manufacturer.

8. Source of Funding

None.

9. Conflict of Interest

None.

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