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Original Article

An In - Vivo Study to Evaluate the Force Decay of Three Different Orthodontic Elastomeric Ligatures.

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Abstract:

Aim & Objectives: The aim of the in-vivo study was to evaluate the force decay of three different clear elastomeric ligatures at four different time intervals.

Materials and methods: Ten patients undergoing fixed orthodontic treatment with 0.019" x 0.025" SS arch wire placed passively in the lower arch were included. The three groups of clear elastomeric ligatures from three different manufacturers were placed on the specific lower incisor assigned to each. The force levels required to stretch the modules to a predetermined length of 4.1mm were evaluated at 0 hour, 24 hours, 7 days and 21 days after intra-oral use using a universal testing machine. One way ANOVA followed by Post hoc Tukey HSD was performed for within the group and between group comparisons. Paired T test was done for pairwise comparisons. (P value$\leq$ 0.05)

Results: The mean force level recorded were high for as received elastomeric ligatures in all the three study groups and all demonstrated a significant force decay over time. One way ANOVA showed a significant difference between the force levels recorded at different time intervals within and between the groups. Post Hoc Tukey HSD revealed a significant difference between the three groups at all the time intervals except at 7 days and 21 days for Group II and Group III samples. Paired sample T test for pairwise comparison of force exerted at different time intervals in all the three groups revealed a significant difference.

Conclusion: Group I elastomeric ligatures exhibited significantly high mean force and less force decay compared to Group II and Group III samples. All the three ligatures exhibited significant force decay over time.

Keywords: Elastomeric ligature, Force decay, Force degradation**,** Mechanical testing

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INTRODUCTION

Elastomeric ligatures are routinely used in orthodontics to engage the arch wire to the bracket slot.[1-3] The force exerted by these modules and the force decay over time vary depending on numerous factors including composition, manufacturing method, the thickness and diameter, additives added, storage environment, oral environment, method of placement and the degree of pre-stretching before placement. [1-6]

Though stainless steel ligatures offer high arch wire seating forces and least amount of friction, elastomeric modules remain popular because of its ease of use, reduced chair side time, less tissue irritation, and its use as elastic tiebacks for retraction.[1,2,7-9] However they attract more plaque, cause binding during sliding, with rapid relaxation of force in the first 24 hours leading to improper seating of arch during torquing or rotational corrections.[2, 8, 9-11] Studies have shown that significant variations present in the mechanical and frictional characteristics of elastomeric ligatures manufactured from the same material.[10, 12-18]

A recent systematic review and meta-analysis by Andhare P et al analyzed the data published from earliest to theyear 2000 and concluded that observed even though not significant a difference existed between the invitro and in-vivo force degradation of elastomeric ligatures and chains.[7] They included 53 studies out of which only ninewere In-vivo studies and only two studies evaluated the in-vivo force decay of elastomeric ligatures and the rest evaluated elastomeric chains. [19, 20]

In vitro laboratory studies may underestimate the loss of material properties and the higher force decay noted in the in-vivo studies may be due to the variations in oral temperature, pH, and mechanical stress and the presence of salivary and bacterial enzymes.[5, 19, 20] Hence this study was aimed to evaluate the force decay of three different clear elastomeric ligatures available in the market under optimal clinical environment over a period of three weeks.

MATERIALS & METHODS

Ten patients undergoing fixed orthodontic treatment in the Department of Orthodontics, SRM Dental College Ramapuram and who gave written consent were included in the study. Patients undergoing treatment with Roth prescription, 0.022" slot preadjusted edgewise stainless-steel brackets (Victory series, 3MUnitek, Monrovia, California) with aligning and levelling completed and 0.019" x 0.025" SS arch wire placed passively in the lower arch were selected.

The clear elastomeric ligature modules supplied by three different manufacturers formed the three study groups [Group I: Molded "O" (Ormco, USA), Group II: Alastik (3M Unitek, USA) and Group III: Uni-stick (American Orthodontics, USA)] (Fig 1).

Fig 1: Clear elastomeric ligature modules belonging to Group I, Group II & Group III

The elastomeric ligatures were bought from a batch with an optimum shelf life and were stored in a cool dry place until used. The modules were remained sealed in their plastic pouches till it was placed in the patient's mouth.

Each elastomeric modules were placed in the patient's mouth on the specified lower incisor brackets (Group I – Lower right lateral incisor, Group II – Lower right central incisor & Group III – Lower left central incisor) in a conventional figure of 'O' pattern using a power shooter module changer (Straight shooter ligature gun, TP orthodontics) with utmost care (Fig 2&3). The modules belonging to each group were evaluated at 4 different timeintervals at 0 hour (as received), 24, 7 days, and 21 days after intra-oral use.

Fig 2: Power shooter module changer

Fig 3: Intra oral photographs showing modules placed in the respective teeth after 24 hrs, 7 days and 21 days respectively

Thirty samples belonging to each group from the 10 patients were retrieved after the specific time interval and replace with fresh modules. The samples were rinsed with distilled water to remove the loosely bound deposits. They were grouped and stored in labelled sterile containers with distilled water and transported to the laboratory and subjected to testing within a time span of 3 hours (Fig 4).

Fig 4: Sterile containers used for transporting the samples to the lab

An Instron universal testing machine (Instron model 1112, Instron Corp.) with a 5 kg load cell was used for this study. A piece of 23 gauge (0.55 mm diameter) stainless steel wire, bent in the form of hook was secured to the lower fixed clamp and a second identical piece of wire parallel to the first wire was attached to the load cell of the testing machine. The modules were placed between the hooks and stretched at the rate of 0.2” (5 mm) per minute as described by Kovatch to a predetermined length of 4.1mm (Fig 5). [20]

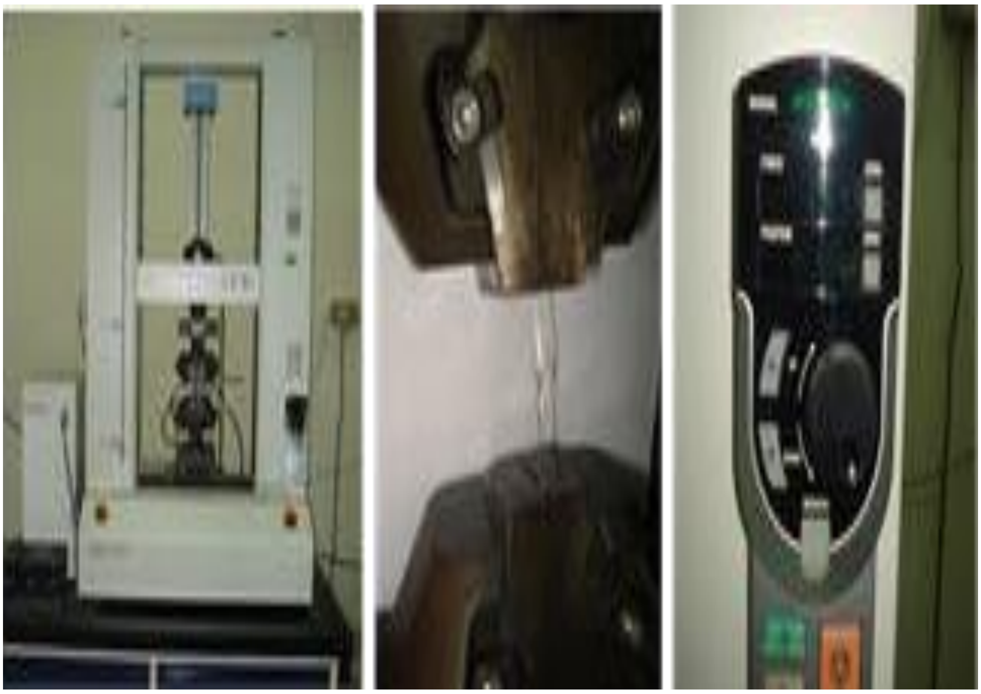

Fig 5: The modules encage the positioning jigs of the Instron universal testing machine and stretched to a predetermined length and the force levels being recorded.

The amount of the stretch (4.1mm) was calculated using the formula D1= 2x + π (D2) Where D1 is the circumference of the elastomeric module stretched over the lower incisor twin bracket, X is the distance necessary to stretch the ligatures on testing machine and D2 is the circumference of the hook. The length of a 0.009" stainless steel ligature wire that required for ligating the bracket corresponds to the circumference of the elastomeric module (D1) when placed over the same bracket.

The highest force levels recorded for all the study groups at a maximum of 4.1mm stretch at each time period was taken. The mean force values and standard deviations for all the groups at each time period and force decay rate were calculated. One way ANOVA followed by Post hoc Tukey HSD was performed for within the group and between group comparisons. Paired T test was done for pairwise comparisons between force levels at different time intervals. A P value lesser than or equal to 0.05 was considered as level of significance.

RESULTS:

The mean force level recorded were high for the as received modules for all the three study groups. The elastomeric modules belonging to the Group I (Power "O", Ormco)] recorded a significantly high mean force level at all the four-time interval tested followed by Group II (Alastik, 3M Unitek) and Group III (Unistick, American Orthodontics). (Table 1 & Table 2)

Table 1: Descriptive statics of force levels exerted by Group I, II and Group III ligature modules at different time intervals in gms

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
0-Hour	Power ormco - Force levels	10	766.50	3.659	1.157	763.88	769.12	760	772
	3 M - Force level	10	650.50	2.759	.872	648.53	652.47	646	655
	American orthodontics - Force levels	10	594.10	4.630	1.464	590.79	597.41	585	599
	Total	30	670.37	73.087	13.344	643.08	697.66	585	772
24-Hours	Power ormco - Force levels	10	511.30	29.341	9.278	490.31	532.29	449	550
	3 M - Force level	10	446.50	30.758	9.727	424.50	468.50	406	510
	American orthodontics - Force levels	10	398.40	25.330	8.010	380.28	416.52	353	436
	Total	30	452.07	54.531	9.956	431.70	472.43	353	550
7-Days	Power ormco - Force levels	10	259.80	26.174	8.277	241.08	278.52	220	296
	3 M - Force level	10	190.20	11.282	3.568	182.13	198.27	173	210
	American orthodontics - Force levels	10	179.10	14.395	4.552	168.80	189.40	150	198
	Total	30	209.70	40.447	7.385	194.60	224.80	150	296
21-Days	Power ormco - Force levels	10	175.40	10.596	3.351	167.82	182.98	155	190
	3 M - Force level	10	131.20	11.717	3.705	122.82	139.58	110	145
	American orthodontics - Force levels	10	122.90	11.789	3.728	114.47	131.33	110	145
	Total	30	143.17	25.882	4.725	133.50	152.83	110	190

Table 2: Percentage of force decay of elastomeric ligatures belonging to Group I II & III

Duration	Group I	Group II	Group III
0 - 24 hrs	33.29%	31.36%	32.94 %
0 - 7days	66.10%	70.76%	69.85%
0 - 21days	77.12%	79.83%	79.31%

The force decay rate Group I (Power "O", Ormco)] modules at 24 hrs, 7 days and 21 days were 33.29%, 66.10% and 77.12% respectively (Table.2). Group II (Alastik, 3M Unitek) the recorded a force decay of 70.76% and 79.83% from the base line value (Table.2). A similar trend of force decay was noted in Group III (Unistick, American Orthodontics) samples where the force decay was 32.94 % at 24 hrs and 69.85% at 7 days and almost 79.31% of the force was lost by 21 days. (Table 2).

One way ANOVA showed a significant difference between the force levels recorded at different time intervals within and between all the three study groups (Table 3).

Table 3: One way ANOVA for comparison of force levels between 3 groups at different time intervals

		Sum of Squares	df	Mean Square	F	Sig.
0-Hour	Between Groups	154529.1	2	77264.533	5462.536	.000
	Within Groups	381.900	27	14.144		
	Total	154911.0	29			
24-Hours	Between Groups	64196.867	2	32098.433	39.327	.000
	Within Groups	22037.000	27	816.185		
	Total	86233.867	29			
7-Days	Between Groups	38266.200	2	19133.100	56.298	.000
	Within Groups	9176.100	27	339.856		
	Total	47442.300	29			
21-Days	Between Groups	15929.267	2	7964.633	61.496	.000
	Within Groups	3496.900	27	129.515		
	Total	19426.167	29			

Post Hoc Tukey HSD for Multiple comparisons between the groups at different time interval revealed a significant difference between the three groups at all the time intervals tested except at 7 days and 21 days where the force levels exerted by the group II (Alastik, 3M Unitek) and Group III samples were not significantly different (Unistick, American Orthodontics) (Table.4).

Table 4: Post Hoc Tukey HSD for Multiple comparisons between the groups at different time interval

Dependent variable	(I)Group	(J) group	Mean difference (I-J)	Std Error	Sig	95% confidence interval	
						Upper bound	Lower bound
0hrs	Group I	Group II	116.000	1.682	.000	111.83	120.17
		Group III	172.400	1.682	.000	168.23	176.57
	Group II	Group III	56.400	1.682	.000	52.23	60.57
24hrs	Group I	Group II	64.800	12.776	.000	33.12	96.48
		Group III	112.900	12.776	.000	81.22	144.58
	Group II	Group III	48.100	12.776	.002	16.42	79.78
7days	Group I	Group II	69.600	8.244	.000	49.16	90.04
		Group III	80.700	8.244	.000	60.26	101.14
	Group II	Group III	11.100	8.244	.383	-9.34	31.54
21 days	Group I	Group II	44.200	5.089	.000	31.58	56.82
		Group III	52.500	5.089	.000	65.12	39.88
	Group II	Group III	8.300	5.089	.250	-4.32	20.92

Paired sample T test for pairwise comparison of force exerted between different time intervals in all the three groups revealed a significant difference (Table.5, 6 & 7).

Table 5: Paired sample T test for pairwise comparison in Group I at different time intervals

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	0-Hour - 24-Hours	255.200	30.084	9.513	233.679	276.721	26.825	9	.000
Pair 2	0-Hour - 7-Days	506.700	26.026	8.230	488.082	525.318	61.567	9	.000
Pair 3	0-Hour - 21-Days	591.100	11.542	3.650	582.844	599.356	161.954	9	.000
Pair 4	24-Hours - 7-Days	251.500	43.523	13.763	220.365	282.635	18.273	9	.000
Pair 5	24-Hours - 21-Days	335.900	31.834	10.067	313.127	358.673	33.367	9	.000
Pair 6	7-Days - 21-Days	84.400	28.214	8.922	64.217	104.583	9.460	9	.000

Table 6: Paired sample T test for pairwise comparison in Group II at different time intervals

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	0-Hour - 24-Hours	204.000	30.761	9.727	181.995	226.005	20.972	9	.000
Pair 2	0-Hour - 7-Days	460.300	10.667	3.373	452.669	467.931	136.456	9	.000
Pair 3	0-Hour - 21-Days	519.300	10.812	3.419	511.566	527.034	151.884	9	.000
Pair 4	24-Hours - 7-Days	256.300	31.875	10.080	233.498	279.102	25.427	9	.000
Pair 5	24-Hours - 21-Days	315.300	26.030	8.231	296.679	333.921	38.304	9	.000
Pair 6	7-Days - 21-Days	59.000	11.294	3.571	50.921	67.079	16.520	9	.000

Table 7: Paired sample T test for pairwise comparison in Group III at different time intervals

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	0-Hour - 24-Hours	195.700	27.785	8.786	175.824	215.576	22.273	9	.000
Pair 2	0-Hour - 7-Days	415.000	13.856	4.382	405.088	424.912	94.710	9	.000
Pair 3	0-Hour - 21-Days	471.200	12.943	4.093	461.941	480.459	115.129	9	.000
Pair 4	24-Hours - 7-Days	219.300	28.083	8.881	199.210	239.390	24.694	9	.000
Pair 5	24-Hours - 21-Days	275.500	26.701	8.444	256.399	294.601	32.628	9	.000
Pair 6	7-Days - 21-Days	56.200	18.329	5.796	43.088	69.312	9.696	9	.000

DISCUSSION:

Rapid force decay is a major disadvantage of elastomeric ligatures which may result in improper seating of arch wires in bracket slot or loss of retraction force when used for canine or en-masse anterior retraction.[5, 16, 22] Studies evaluating the force decay of elastomeric ligatures are limited to invitro studies with only very few in-vivo studies.[19, 20] The time intervals used in the study were taken assuming that elastomers are changed between third and fourth week and the force decay between 3rd and 4th week was no greater than 2% as reported by Young et al.[23- 25] The samples were transported in sterile containers with distilled water, because dry samples could record moreforce levels due to dehydration of the material.[23]

The group with higher force levels after 24 hours, 3 weeks, 7 days was found to be Group I followed by Group II followed by Group III. The possible reasons for the intra group variation in this study may be differences in the dimension of the modules and deterioration of the material. Most of the decay in force occurred within the first day and continued at a slower rate during the rest of the three-week period. This is in concurrent with the previousin-vivo studies conducted with elastomeric ligatures.[7, 19, 21] The variation in the force level between the groups might be due to the difference in the material properties as suggested by Kuster et al and another reason could be because of the difference in the inner diameters and wall thickness as suggested by Taloumis.[2, 15]

The percentage of force loss at 24 hrs was highest in Group I followed by Group III and Group II. After one week and 21 days the force decay was highest in Group II followed by Group III and Group I. The samples from Group I had higher initial mean force levels, and percentage of force decay less as compared to the other study groups. This finding was in contrast with Kovatch Lu et al and who found that, greater the initial force, greater the force decay.[21,25] This may be due to the improvement in the material science including superior ingredients, morphological characteristics and improved methods of manufacturing.

The result of this study shows that the selection of ligatures should not be based on the clinician's loyalty to a particular company, cost of the ligatures, the variety of sizes and colors available, the clinical feel of the ligatures but also on the mechanical properties of the concerned product. Elastomeric ligatures tested in this study demonstrated a low residual force after 21 days and therefore elastomeric ligatures can be useful in the initial aligning and levelling phase of orthodontics and change of modules every three weeks could be beneficial. But if the properties of force decay are taken into consideration, stainless steel ligatures ought to be the better choice of ligation especially in the later stages of orthodontic treatment.

CONCLUSION

Group I elastomeric ligatures exhibited significantly high mean force level followed by Group II and Group III modules at all four-time intervals tested. The force exerted by the three elastomeric ligatures were significantly different at all-time intervals tested except in group II and Group III samples at 7 and 21 days. Group I elastomeric ligatures exhibited significantly less force decay compared to Group II and Group III. The remaining forces available at the end of three weeks of intra oral use appeared to be insufficient for effective torquing effect and severe rotational corrections in all the three study groups and hence changing modules after three weeks may be beneficial in those cases.

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None

CONFLICT OF INTEREST

There is no conflict of interest.

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