Original Article

A study of force extension and force degradation of orthodontic latex elastics: An *in vitro* study

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Abstract

Introduction: The purpose of this study was to determine the force values of different orthodontic latex elastics at different extensions when subjected to testing in dry and wet conditions. This study also aims to determine and compare the force degradation of the elastics produced by four manufacturers at different extensions and at regular intervals. **Materials and Methods:** 5/16 inch lumen medium (Green) and ¼ inch lumen medium elastics (blue) of 4 companies were used. The elastics were stretched on a correx gauge to two times and three times the inner lumen diameter and at a fixed distance of 25 mm (dry test).The elastics were stretched at the specific distances and then immersed in artificial saliva and checked after 24 and 48 h (wet test). The data was analyzed using Student's *t*-test. **Results:** Force degradation increases with time. Force degradation percentage values vary from 5% to a maximum of 25%. **Conclusions:** Thus from the study, the clinician can know the force degradation rates of elastics of two different sizes, manufactured by four different companies. This study also shows that though, the force degradation during the 2nd day was found to be significant in most of the elastics, it is not sufficient to justify daily change of elastics.

Key words: Force decay, force degradation, latex elastics

INTRODUCTION

Latex elastics have remained one of the most commonly used force delivery systems. The advantages of latex elastics include an ability to exert a continuous force, convenience of use, compatibility in the oral environment and cost-effectiveness.[1]

One of the inherent disadvantages of elastics is that the force levels decrease over time. This property is termed "force decay." For optimum orthodontic tooth movement this force decay has to be within acceptable limits.

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The standard index employed by a majority of orthodontic elastic manufacturers says that when the elastic is stretched to 3 times the inner lumen diameter (3×), it will exert the force levels stated on the package.[1]

The purpose of this study was to evaluate the initial force and force decay pattern of elastics at 25 mm, 2× and 3× of inner lumen diameter. This will help in determining the appropriate time for change of elastics for maintaining optimum orthodontic force. The present study also compares the force decay values of elastics manufactured by 4 companies.

MATERIALS AND METHODS

Orthodontic latex elastics marketed by 4 companies (HP company-Calicut, Kerala India; JJ company-Chalakudy, Kerala India; AO company-Sheboygan USA; TP company-Laporte, USA) were tested. An acrylic board was prepared having sets of stainless steel pins set at a fixed distance of 25 mm between them, which was considered to cover

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the range that the elastic would be stretched under clinical conditions and at 2 times and 3 times (i.e., 2× and 3×) their inner lumen diameter for 5/16" diameter medium (green) and ¼" diameter medium elastics (blue). These particular sizes were selected as they are the most commonly used elastics in orthodontic practice.

Correx force gauge (HP company-Calicut, Kerala, India) was used to measure the force in grams exerted by the elastics. The force range of the gauge is 25-250 g.

The Correx force gauge was mounted together with a ruler so that force exerted by the elastic at given length could be noted.

Two tests were carried out.

Dry test

This test was done to analyze, the initial values of force extension in the elastics (zero hour value). In this test, 10 samples of each size of all 4 companies were tested. Each elastic was stretched by continuous extension and force values were recorded at 25 mm and at 2× and 3× the inner diameter of the elastic.

Wet test

This test was carried out to evaluate the force degradation of elastics in artificial saliva, i.e., in a simulated oral environment. A total of 30 samples of each size of all the 4 companies were picked at random to be tested. A total of 10 elastics each were stretched at 25 mm and also at 2× and 3× the inner diameter of the elastic and was immersed in artificial saliva and kept in an incubator at 37°C to simulate the oral environment. After 24 h, the elastics were removed from the stainless steel pins with the help of a pair of tweezers. The elastics were then extended the same distance on the Correx gauge and the force value was recorded. The elastic were then replaced on the stainless pins and the reading was again recorded at 48 h. All the measurements were done by one observer to eliminate interobserver errors. The readings were then subjected to statistical analysis.

Statistical analysis

The data was analyzed using Students *t*-test.

RESULTS

The results of the present study were as follows:

- Force values obtained in this study at 3× extension were found to be closer to the force values mentioned by the manufacturer rather than force values at 2× [Table 1].
- A considerable margin of error was found between the actual force value of the elastic and value indicated by the manufacturer with JJ and AO Company. Their elastics showed lesser force values than those mentioned by manufacturer [Table 1].
- HP and TP Company elastics show nearly the same force values as those mentioned by the manufacturer [Table 1].
- The property of "Force Degradation" was found in all types of elastics. Force degradation increases with time [Tables 2, 3, 4 and 6].
- Greatest force degradation of nearly 20% occurs during the 1st day [Tables 2 and 3].
- 5-10% force degradation was found during the 2nd day [Tables 2, 3, 4 and 6].

On comparing, the force degradation values of HP and JJ Company, i.e., two Indian companies it was seen that 5/16 inch lumen medium HP elastics show lower force degrading qualities than 5/16 inch lumen medium JJ elastics [Table 5].

Conversely, ¼ inch lumen medium JJ elastics show lower force degrading qualities than ¼ inch lumen medium HP elastics [Table 7].

On comparing the force degradation values of HP and TP company, i.e., one Indian and one American company it was seen that 5/16 inch lumen medium HP elastics have lower force degrading qualities than 5/16 inch lumen medium TP elastics [Table 5]. Conversely, ¼ inch lumen medium TP elastics show lower force degrading qualities than ¼ inch lumen medium HP elastics [Table 7].

Table 1: Dry test values at 25 mm and at 2× and 3× extension

Company	Size	Force value advocated	Zero hour force value		
		By manufacturer	2×	3×	25 mm
HP	5/16 medium (green)	99.22 g (3½ Oz)	58	105.5	111
	¼ medium (blue)	99.22 g (3½ Oz)	52.5	99.5	133
JJ	5/16 medium (green)	99.22 g (3½ Oz)	39.5	76	80
	¼ medium (blue)	99.22 g (3½ Oz)	42	75.5	107.5
TP	5/16 medium (green)	99.22 g (3½ Oz)	58	90.5	95.5
	¼ medium (blue)	99.22 g (3½ Oz)	53	86	110
AO	5/16 medium (green)	127.57 g (4½ Oz)	56	110	119.5
	¼ medium (blue)	127.57 g (4½ Oz)	67	102	133.5

Table 2: Mean, standard deviation, percentage deviation, co-efficient of variance of 5/16 medium (green) elastic at 25 mm, 2× and 3× extension

Company	Parameter	2×			3×			25 mm		
		0 h	1 day	2 days	0 h	1 day	2 days	0 h	1 day	2 days
HP	Mean	58	46.5	43.5	105.5	84	80.5	111	89	86.5
	Standard deviation	4.21	3.37	4.11	8.95	6.14	4.97	8.75	6.14	6.25
	Percentage degradation		18.49	21.32		20.38	23.7		19.82	22.07
	Coefficient of variance	7.26	7.25	9.45	8.48	7.3	6.17	7.88	6.9	7.22
JJ	Mean	39.5	32	30	76	60	57.5	80	61.5	57
	Standard deviation	4.97	4.21	4.08	8.09	3.33	2.63	8.49	4.11	4.21
	Percentage degradation		18.99	24.05		21.05	24.34		23.13	28.75
	Coefficient of variance	12.58	13.16	13.6	10.64	5.55	4.57	10.61	6.68	7.38
TP	Mean	58	46.5	42.5	90.5	70	66.5	95.5	70.5	66
	Standard deviation	6.32	4.73	4.85	8.64	4.71	4.11	8.64	4.37	5.16
	Percentage degradation		19.83	26.72		22.85	26.52		26.18	30.89
	Coefficient of variance	10.89	10.17	11.41	9.55	6.73	6.18	9.05	6.2	7.82
AO	Mean	56	47.5	44.5	110	85	82	119.5	96	92.5
	Standard deviation	3.94	2.63	2.83	7.07	5.27	5.37	4.97	8.75	8.89
	Percentage degradation		15.18	20.54		22.73	25.45		19.67	22.59
	Coefficient of variance	7.03	5.53	6.36	6.43	6.2	6.55	4.16	9.11	9.61

Table 3: Mean, standard deviation, percentage deviation, co-efficient of variance of ¼ medium (blue) elastic at 25 mm, 2× and 3× extension

Company	Parameter	2×			3×			25 mm		
		0 h	1 day	2 days	0 h	1 day	2 days	0 h	1 day	2 days
HP	Mean	52.5	39	35.5	99.5	72.5	68.5	133	100	97
	Standard deviation	4.24	5.16	3.68	4.97	2.63	3.37	6.32	5.27	5.37
	Percentage degradation	—	25.71	32.38	—	27.14	31.16	—	24.81	27.07
	Coefficient of variance	8.08	13.23	10.36	4.99	3.63	4.92	4.75	5.27	5.53
JJ	Mean	42	34	31	75.5	61.5	59	107.5	86.5	83
	Standard deviation	5.37	5.67	3.94	12.34	7.09	6.99	19.61	6.68	6.32
	Percentage degradation	—	19.05	26.19	—	18.54	21.85	—	19.53	22.79
	Coefficient of variance	12.78	16.68	12.71	16.34	11.52	11.85	18.24	7.72	7.61
TP	Mean	53	44.5	39.5	86	70.5	65.5	110	92.5	87.5
	Standard deviation	6.32	5.98	5.98	5.67	4.37	4.97	5.27	4.85	3.53
	Percentage degradation	—	16.04	25.47	—	18.02	23.84	—	15.91	20.45
	Coefficient of variance	11.92	13.43	15.13	6.59	6.2	7.58	4.79	5.24	4.03
AO	Mean	67	53.5	51	102	85.5	82	133.5	111	108
	Standard deviation	6.32	4.74	5.67	8.88	3.68	5.86	11.79	3.94	4.21
	Percentage degradation	—	20.15	23.88	—	16.18	19.61	—	16.85	19.1
	Coefficient of variance	9.43	8.86	11.11	8.7	4.3	7.15	8.83	3.55	3.9

Table 4: Force degradation of 5/16 medium (green) elastic at 25 mm, 2× and 3× extension in artificial saliva comparing mean changes from 0 h to 1 day, 1 day to 2 day

Company	Time	2×				3×				25 mm			
		Mean changes	SE	*t*-value	*P* value	Mean changes	SE	*t*-value	*P* value	Mean changes	SE	*t*-value	*P* value
HP	0-1 day	11.5	1.67	6.86	0.0001	21.5	3.08	6.98	0	22	3.18	6.92	0.0001
	1-2 days	3	0.82	3.67	0.0051	3.5	1.07	3.28	0.0095	2.5	0.83	3	0.015
JJ	0-1 day	7.5	1.12	6.71	0.0001	16	2.21	7.24	0	18.5	2.11	8.74	0
	1-2 days	2	0.82	2.45	0.0368	2.5	1.11	2.24	0.0522	4.5	0.5	9	0
TP	0-1 days	11.5	2.11	5.44	0.0004	20.5	2.41	8.51	0	25	3.5	7.15	0.0001
	1-2 days	4	0.67	6	0.0002	3.5	0.76	4.59	0.0013	4.5	0.9	5.01	0.0007
AO	0-1 day	8.5	1.3	6.52	0.0001	25	2.58	9.68	0	23.5	3.08	7.63	0
	1-2 days	3	0.82	3.67	0.0051	3	0.82	3.67	0.0051	3.5	0.76	4.58	0.0013

SE: Standard error

Table 5: Comparison of force degradation of 5/16 medium (green) elastic at 25 mm and at 2× and 3× extension among the four companies

Company	Time	2×				3×				25 mm			
		Mean changes	SE	*t*-value	*P* value	Mean changes	SE	*t*-value	*P* value	Mean changes	SE	*t*-value	*P* value
HP/JJ	0-1 day	3.5	3.33	1.05	0.3217	5.5	3.28	1.67	0.1286	3.5	3.33	1.05	0.3217
	1-2 days	2	0.81	2.44	0.0368	1	1	1	0.3434	2	0.81	2.44	0.0368
HP/TP	0-1 day	3	4.48	0.67	0.5203	1	4.13	0.24	0.8144	3	4.48	0.67	0.5203
	1-2 days	2	1.52	1.31	0.2229	0	1.49	0	1	2	1.52	1.31	0.2229
HP/AO	0-1 day	1.5	5.22	0.29	0.7804	3.5	4.53	0.77	0.4602	1.5	5.22	0.29	0.7804
	1-2 days	1	1.45	0.68	0.5086	0.5	1.57	0.32	0.7577	1	1.45	0.68	0.5086
JJ/TP	0-1 day	6.5	4.59	1.41	0.1911	4.5	3.83	1.17	0.2706	6.5	4.59	1.41	0.1911
	1-2 days	0	1.05	0	1	1	1.45	0.69	0.5086	0	1.05	0	1
JJ/AO	0-1 day	5	3.57	1.4	0.1954	9	3.39	2.65	0.0266	5	3.57	1.4	0.1954
	1-2 days	1	1	1	0.3434	0.5	1.57	0.32	0.7577	1	1	1	0.3434
TP/AO	0-1 day	1.5	6.01	0.25	0.808	4.5	3.97	1.13	0.2869	1.5	6.01	0.25	0.8086
	1-2 days	1	0.67	1.5	0.167	0.5	0.89	0.56	0.5911	1	0.67	1.5	0.1679

SE: Standard error

Table 6: Force degradation of ¼ medium (blue) elastic at 25 mm, 2× and 3× extension in artificial saliva comparing mean changes from 0 h to 1 day, 1 day to 2 days

Company	Time	2×				3×				25 mm			
		Mean changes	SE	*t*-value	*P* value	Mean changes	SE	*t*-value	*P* value	Mean changes	SE	*t*-value	*P* value
HP	0-1 day	13.5	1.67	8.06	0	27	1.53	17.67	0	33	2.81	11.75	0
	1-2 days	3.5	0.67	4.58	0.0013	4	1	4	0.0031	3	0.82	3.67	0.0051
JJ	0-1 day	8	1.53	5.24	0.0005	14	3.48	4.02	0.003	21	6.14	3.42	0.0076
	1-2 days	3	0.82	3.67	0.0051	2.5	0.83	3	0.015	3.5	1.07	3.28	0.0095
TP	0-1 day	8.5	1.5	5.67	0.0003	15.5	2.73	5.67	0.0003	17.5	2.27	7.72	0
	1-2 days	5	1.05	4.74	0.0011	5	1.29	3.87	0.0038	5	1.49	3.35	0.0085
AO	0-1 day	13.5	2.99	4.52	0.0014	16.5	2.73	5.52	0.0004	22.5	4.23	5.31	0.0005
	1-2 days	2.5	0.83	3	0.015	3.5	1.07	3.27	0.0095	3	0.82	3.67	0.0051

SE: Standard error

Table 7: Comparison of force degradation of ¼ medium (blue) elastic at 25 mm and at 2× and 3× extension among the 4 companies

Company	Time	2×				3×				25 mm			
		Mean changes	SE	*t*-value	*P* value	Mean changes	SE	*t*-value	*P* value	Mean changes	SE	*t*-value	*P* value
HP/JJ	0-1 day	5.5	2.17	2.54	0.0316	13	3.88	3.34	0.0086	12	7.71	1.55	0.1544
	1-2 days	0.5	0.89	0.56	0.5911	1.5	1.3	1.15	0.2789	0.5	1.17	0.43	0.6783
HP/TP	0-1 day	5	2.1	2.37	0.0418	11.5	2.89	3.98	0.0032	15.5	4.5	3.44	0.0073
	1-2 days	1.5	1.3	1.15	0.2789	1	1.45	0.69	0.5082	2	1.85	1.08	0.3093
HP/AO	0-1 day	0	2.1	0	1	10.5	2.62	3.99	0.0031	10.5	5.6	1.87	0.0936
	1-2 days	1	1.24	0.8	0.4433	0.5	1.38	0.36	0.7263	0	1.05	0	1
JJ/TP	0-1 day	0.5	2.62	0.19	0.8534	1.5	4.21	0.35	0.7304	3.5	5.91	0.59	0.5688
	1-2 days	2	1.33	1.5	0.1679	2.5	1.86	1.34	0.2126	1.5	1.5	1	0.3434
JJ/AO	0-1 day	5.5	3.2	1.72	0.1199	2.5	6.02	0.41	0.6877	1.5	8.94	0.17	0.8705
	1-2 days	0.5	0.89	0.56	0.5911	1	1	1	0.3434	0.5	1.38	0.36	0.7263
TP/AO	0-1 day	5	3.16	1.58	0.1433	1	3.71	0.27	0.7937	5	3.57	1.4	0.1954
	1-2 days	2.5	1.34	1.86	0.0957	1.5	1.67	0.89	0.3938	2	1.85	1.08	0.3092

SE: Standard error

Similarly when the elastics of HP and AO company, i.e., one Indian and one American company were compared it was observed that 5/16 inch lumen medium elastics of HP company show nearly similar force degradation qualities than 5/16 inch lumen medium AO elastics [Table 5]. Although ¼ inch lumen medium AO elastics

show lower force degrading qualities than ¼ inch lumen medium HP elastics [Table 7].

On comparison of elastics of JJ Company and TP Company, it was observed that 5/16 inch lumen medium JJ elastics show lower force degradation than 5/16 inch lumen medium TP elastics [Table 5]. Conversely, ¼ inch lumen medium TP elastics show lower force degrading qualities than ¼ inch lumen medium JJ elastics [Table 7].

On comparison of elastics of JJ Company and AO Company, it was observed that 5/16 inch lumen medium AO elastics show lower force degradation than 5/16 inch lumen medium JJ elastics [Table 5]. Similarly, ¼ medium AO elastics show lower force degrading qualities than ¼ medium JJ elastics [Table 7].

Finally on comparison of elastics of AO Company and TP company, i.e., two American companies it was observed that 5/16 inch lumen medium AO elastics show lower force degradation than 5/16 inch lumen medium TP elastics [Table 5]. Similarly, ¼ inch lumen medium AO elastics show lower force degrading qualities than ¼ inch lumen medium TP elastics [Table 7].

Thus, from the above comparison we can conclude that 5/16 inch lumen medium elastics are more resistant to force. Conversely, ¼ inch lumen medium elastics show poor force degradation. In ¼ inch lumen medium elastics least force degradation is present in AO elastics.

DISCUSSION

The present study has measured force values of elastics of 2 sizes at 25 mm, which covers the range that the elastic will be stretched under clinical conditions. The elastics were also stretched at 2 times (2×) and at 3 times (3×) their inner lumen diameter and tested for force value changes in a simulated oral environment.

Bales *et al*.[2] had investigated the accuracy of force values at 3× inner lumen diameter index and had reported that a closer relationship of observed force values occurred at 2× stretch rather than at 3× stretch. Gupta *et al*.[3] stated that the expected force values of elastic as stated in the manufacturers catalogue will be delivered at 3× stretch rather than at 2× stretch. It was observed in our study that force values at 3× were closer to the force values mentioned by the manufacturers on the elastic packet than force values at 2×. Thus, our study shows that the elastics exert forces as specified by the manufacturers standard extension index.

The present study showed that all the elastics regardless of brand or size underwent degradation in force with time. The average force degradation after 1 day ranged from a minimum of 16.04% for ¼ inch lumen medium elastics of TP Company to a maximum of 27.14% for ¼ inch lumen medium elastics of HP Company. This was in accordance with the results of other studies.[4-7]

Similarly, average force degradation after 2nd day ranged from a minimum of 19.01% for ¼ inch lumen medium elastics of AO Company to a maximum of 32% for ¼ inch lumen medium elastics of AO Company. On considering force degradation percentile values of all elastics there was about 20.84% during the 1st day, which increased to 25.54% on the 2nd day. This was in accordance with the various studies[4-7] carried out on force degradation of latex elastics with a range of 7-30% from 1 h to 3 days. The difference in force degradation values can be attributed to different experimental conditions, stretching criteria and sample differences.

The factors that influence the force degradation characteristics of elastics are — Plant to plant variation, regional and seasonal variation before the manufacturing process and also the presence of impurities in raw material.[8] The difference in force degradation characteristics of the elastics compared in this study can be attributed to differences during manufacture, i.e., the type, extent and the material that has been used for cross linking, inclusion of protective materials such as antioxidants and procedures such as bleaching. Before use, of the elastics after manufacture, exposure to sunlight, moisture, heat, ozone and radiations can affect the characteristics of the elastics; whereas during use, the masticatory forces, temperature variations, dietary habits and stretching cycles also play a role.[9]

CONCLUSION

- Force values obtained in this study at 3× extension were found to be closer to the force values mentioned by the manufacturer rather than force values at 2×.
- The property of "Force Degradation" was found in all types of elastics. Force degradation increases with time with the highest i.e. nearly 20% occurring during the 1st day and 5-10% occuring during the 2nd day.
- A considerable margin of error was found between the actual force value of the elastic and value indicated by the manufacturer with JJ and AO Company. HP and TP Company elastics show nearly the same force values as those mentioned by the manufacturer.

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