

Force of colored intermaxillary latex elastics from different suppliers: A comparative *in vitro* study

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Background: Colored orthodontic latex elastics are increasingly popular among younger patients, yet their mechanical behavior may vary. Differences in force delivery and degradation over time can compromise treatment efficiency. Understanding the force–extension relationship and relaxation behavior of these elastics is essential to ensure continuous, optimal orthodontic forces.

Objectives: This study evaluated and compared the standard force–extension index (three times the lumen diameter), initial force delivery, and force degradation of colored intermaxillary latex elastics from different manufacturers, with varying lumen diameters and declared force values, under simulated oral conditions.

Materials and Methods: This *in vitro* study assessed the force characteristics of colored intermaxillary latex elastics from three manufacturers: American Orthodontics® (Sheboygan, WI, USA), AURAdontics, Inc. (Riverside, NJ, USA), and G&H Orthodontics® (Franklin, TN, USA). A total of 180 elastics (15 per group) were tested, yielding 1,080 force measurements. Elastics with declared forces of 4.5 oz from all manufacturers and 6.5 oz elastics from G&H were included in three lumen diameters (3/16, 1/4, 5/16 in).

The standard force–extension index was determined by stretching each elastic to three times its lumen diameter. To simulate oral conditions, elastics were extended to fixed distances (14.29, 19.05, 23.81 mm), immersed in distilled water at 37°C, and measured at baseline and after 1, 3, 6, 12, and 24 hours. Statistical analyses compared force values across manufacturers, lumen diameters, declared force levels, and time intervals.

Results: The standard force–extension index varied from -34.30% to 16.70%. Elastics with declared 4.5-oz forces showed closer agreement with the standard index (mean 1.13%) than 6.5-oz elastics (mean -26.84%). All elastics exhibited rapid force loss within the first hour, followed by a gradual decline. After 24 hours, the remaining force averaged 60.87% for 4.5-oz elastics and 69.71% for 6.5-oz elastics.

Conclusion: Declared and actual forces differed significantly among manufacturers. Colored elastics degraded quickly, especially within the first hour, underscoring the need for frequent replacement to maintain effective orthodontic force delivery.

Keywords: colored intermaxillary latex elastics, force degradation, force extension, orthodontic elastics

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Introduction

Optimal orthodontic force is a delicate balance, typically ranging from 50 to 100 cN, sufficient to induce effective tooth movement while minimizing adverse effects such as root resorption and discomfort [1]. Light, continuous forces are preferred to achieve efficient movement with minimal biological side effects. Various auxiliaries

deliver orthodontic forces, including coil springs, elastics, elastomeric chains, and ligatures. Intermaxillary elastics, widely used for their effectiveness, depend heavily on patient cooperation [2]. Clinicians must understand the force–extension relationship and relaxation behavior of elastics, as these properties directly influence treatment outcomes [3, 4]. Natural rubber latex has long been the primary material

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due to its favorable elasticity, but it presents disadvantages such as environmental degradation, allergic reactions, and progressive force loss. Latex hypersensitivity affects 3–17% of individuals, with manifestations ranging from oral lesions to anaphylaxis [4]. Consequently, synthetic polymers such as polyurethane have been introduced, though one study reported that latex elastics delivered greater initial force and underwent greater degradation than latex-free types [5].

Pre-vulcanized latex elastics, produced with stabilizers and controlled heating, show enhanced mechanical strength but raise biocompatibility concerns [6,7]. Force degradation is well documented, characterized by a rapid initial loss followed by gradual decline. Some authors have suggested applying higher initial forces to compensate, though this lacks strong scientific support [8]. Colored orthodontic elastics have gained popularity, particularly among younger patients, with preferences varying by age and gender [9,10]. Although the availability of different colors may enhance patient cooperation and compliance during orthodontic treatment, evidence regarding their mechanical properties and degradation patterns across manufacturers remains limited [2]. Furthermore, patients' color preferences for intermaxillary latex elastics have scarcely been reported. At present, colored orthodontic elastics are less commonly used because their mechanical performance is inferior to that of conventional elastics. Nevertheless, their availability may still contribute to patient engagement. Previous studies have shown that younger patients tend to prefer colored ligatures, whereas older patients favor less conspicuous options [9]. Accordingly, the aim of this study was to evaluate these aspects. A systematic evaluation of their force-extension properties and degradation characteristics is therefore essential to guide evidence-based clinical decisions [10].

The present study aimed to assess the standard force index and force degradation of colored intermaxillary latex elastics with different lumen diameters, declared force values, and manufacturers over a 24-hour period under simulated oral conditions.

Materials and Methods

This in vitro study evaluated 180 colored intermaxillary latex elastics (15 per group) from three manufacturers: American Orthodontics® (Sheboygan, WI, USA), AURAdontics, Inc. (Riverside, NJ, USA), and G&H Orthodontics® (Franklin, TN, USA). Elastics with declared forces of 4.5 oz from all suppliers and 6.5 oz from G&H Orthodontics® were tested in three lumen diameters (3/16, 1/4, and 5/16 in). In total, 1,080 force measurements were obtained. All elastics were within expiration dates, delivered within two weeks, manufactured within two months, and stored in sealed containers until testing.

Force measurements were performed using a Universal Testing Machine (Lloyd Instruments Ltd., Fareham, England) with a 500 N load cell (accuracy ± 0.01 mm). For dry testing, elastics were stretched to three times their lumen diameter, and tensile forces were recorded in Newtons (N).

To simulate intraoral conditions, elastics were mounted between stainless steel pins on acrylic boards at fixed extensions (14.29, 19.05, and 23.81 mm), corresponding to three times the lumen diameter. Boards were immersed in distilled water at $37^{\circ}\text{C} \pm 0.1^{\circ}\text{C}$ in a temperature-controlled water bath (Thermo Scientific Model DL 30, Thermo Electron (Karlsruhe) GmbH, Germany). Forces were measured at baseline and after 1, 3, 6, 12, and 24 hours. At each interval,

elastics were removed and tested on the Universal Testing Machine. Calibration was performed before and during each session to ensure accuracy.

Statistical and analysis

Sample size was calculated using GraphPad Prism 7.0 (GraphPad Inc., La Jolla, CA, USA) based on an estimated standard deviation of 7%, statistical power of 80%, a minimum detectable difference of 10%, and six comparisons. A pilot study supported a sample size of 15 specimens per group. Data were recorded in spreadsheets and analyzed with SPSS 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were expressed as means and standard deviations. The force degradation between and within groups of colored intermaxillary elastics was analyzed using repeated-measure ANOVA to assess the effects of material, lumen size, extension, and time interval. In addition, force degradation across the study period was evaluated with Bonferroni Post Hoc comparisons, to compare results within groups over time, to indicate which time points differ significantly from baseline, and finally, to show time-to-time comparisons. A significance level of $p < 0.05$ was adopted. Results were reported as mean values, with variability expressed as standard deviation. Finally, Spearman's correlation coefficient (ρ) evaluated associations between force loss, force magnitude, and elastic size. For clinical interpretation, forces were converted from Newtons to grams and ounces (1 N = 101.97 gf; 1 oz = 28.35 g; 4.5 oz = 127.57 gf; 6.5 oz = 184.27 gf).

Results

Initial Force

Table I summarizes the means, standard deviations, range, and percentage deviations of initial forces obtained from dry testing relative to the standard force–extension index at three times the lumen diameter. No samples fractured during testing. All elastics produced initial forces significantly different from manufacturers' declared values ($p < 0.001$), indicating poor conformity with specifications.

The greatest deviation was observed in the 3/16 inch G&H Neon 6.5 oz elastics (-34.30%), while the closest agreement was found in the 3/16 inch AU Neon 4.5 oz elastics (-1.04%). Overall, deviations ranged from -34.30% to +13.77%. By declared force level, 4.5 oz elastics showed near agreement with the standard index (mean deviation 1.13%), whereas 6.5 oz elastics demonstrated substantially lower values (mean deviation -26.84%).

Measured initial forces differed significantly from manufacturers' declared values in most groups, except for the 3/16-inch AU Neon 4.5-oz and 5/16-inch AO Neon 4.5-oz elastics. The 3/16-inch AU Neon 4.5-oz elastics showed the closest agreement (declared 127.57 gf vs. measured 126.24 gf; -1.04%). In contrast, the greatest discrepancy was observed in the 3/16-inch G&H Neon 6.5-oz elastics (declared 184.27 gf vs. measured 121.07 gf; -34.30%).

Overall, standard force–extension indices ranged from -34.30% to +13.77%. Elastics declared as 6.5 oz consistently delivered lower initial forces and exhibited greater variability than 4.5-oz elastics. The 1/4-inch G&H Neon 6.5-oz elastics averaged 149.35 gf, below the declared 184.27 gf. The lowest initial forces were recorded in the 1/4-inch AU Neon 4.5-oz (105.09 gf) and 5/16-inch G&H Neon 4.5-oz (108.29 gf) elastics. The greatest variability occurred in the 3/16-inch G&H Neon 6.5-oz group (SD = 26.26 gf).

Table 1 Comparisons of overall percentage variations from the manufacturer's force extension indexes of elastics in dry tests for 3 times lumen diameters.

Types	3 x Internal Diameter	Mean (SD)	Range	Overall percentage variation of force*	P-value
4.5 oz (127.57 gf)					
6.5 oz (184.27 gf)					
3/16" AU NEON 4.5 (oz)	(0.56 inch, 14.29 mm)	126.24±6.54	119.31-137.66	-1.04	0.44
3/16" GH NEON 4.5 (oz)		142.08±7.37**	130.52-150.92	+11.37	<0.0001
3/16" AO NEON 4.5 (oz)		148.88±5.97**	141.74-159.08	+16.7	<0.0001
3/16" GH NEON 6.5 (oz)		121.07±26.16**	91.77-153.98	-34.3	<0.0001
1/4" AU NEON 4.5 (oz)	(0.75 inch, 19.05 mm)	105.09±7.55**	90.75-115.23	-17.62	<0.0001
1/4" GH NEON 4.5 (oz)		133.31±7.01**	123.39-147.86	+4.5	0.006
1/4" AO NEON 4.5 (oz)		145.14±8.20**	131.54-159.08	+13.77	<0.0001
1/4" GH NEON 6.5 (oz)		149.35±12.57**	133.58-180.49	-18.95	<0.0001
5/16" AU NEON 4.5 (oz)	(0.94 inch, 23.81 mm)	117.33±5.21**	108.09-127.46	-8.02	<0.0001
5/16" GH NEON 4.5 (oz)		108.29±4.72**	102.99-118.29	-15.11	<0.0001
5/16" AO NEON 4.5 (oz)		134.73±17.84	116.25-173.35	+5.61	0.142
5/16" GH NEON 6.5 (oz)		133.99±7.10**	124.41-148.88	-27.28	<0.0001

*Minus (-) values indicate a percentage less than the standard force index. Plus (+) values indicate a percentage more than the standard force index.

**Paired *t*-test comparisons were used to compare actual forces generated with the standard elastic index ($p < 0.001$).

Because of wide variation in initial forces, degradation was expressed as percentage relaxation rather than absolute values. Table II summarizes degradation percentages for 4.5-oz and 6.5-oz elastics across lumen sizes and at various time points.

Table 2 Extension force (gf) and percentage of force degradation at the various time points accessed (%)

Group	0h	1h	3h	6h	12h	24h
3/16" AU NEON 4.5 (oz)	126.24 ± 6.54	98.16 ± 6.11	86.13 ± 6.03	79.88 ± 6.42	78.86 ± 6.51	78.18 ± 6.96
	0.00	-22.24 ± 2.94	-31.77 ± 2.98	-36.73 ± 3.41	-37.53 ± 3.34	-38.07 ± 4.55
3/16" GH NEON 4.5 (oz)	142.08 ± 7.37	104.42 ± 5.74	93.67 ± 6.15	87.56 ± 6.08	86.34 ± 5.79	84.09 ± 5.53
	0.00	-26.50 ± 2.49	-34.07 ± 3.44	-38.37 ± 3.48	-39.23 ± 3.40	-40.81 ± 3.26
3/16" AO NEON 4.5 (oz)	148.88 ± 5.97	108.77 ± 4.82	100.81 ± 4.43	93.27 ± 3.79	91.84 ± 3.84	89.73 ± 3.80
	0.00	-26.94 ± 3.04	-32.28 ± 2.68	-37.35 ± 2.50	-38.31 ± 2.45	-39.77 ± 2.24
3/16" GH NEON 6.5 (oz)	121.07 ± 26.16	99.45 ± 18.35	91.43 ± 16.50	84.84 ± 18.74	83.01 ± 18.78	79.47 ± 18.70
	0.00	-17.85 ± 4.78*	-24.48 ± 4.62*	-29.92 ± 2.87*	-31.44 ± 2.81*	-34.36 ± 2.91*
1/4" AU NEON 4.5 (oz)	105.09 ± 7.55	77.09 ± 6.70	69.4 ± 5.89	64.51 ± 6.18	63.97 ± 5.67	62.20 ± 6.18
	0.00	-26.65 ± 2.60	-33.96 ± 2.46	-38.61 ± 2.87	-39.13 ± 2.80	-40.82 ± 3.48
1/4" GH NEON 4.5 (oz)	133.31 ± 7.01	101.97 ± 5.86	90.75 ± 6.24	84.02 ± 5.86	83.07 ± 5.97	81.24 ± 5.93
	0.00	-23.51 ± 2.71	-31.92 ± 2.67	-36.97 ± 2.75	-37.68 ± 2.90	-39.06 ± 2.95
1/4" AO NEON 4.5 (oz)	145.14 ± 8.20	104.76 ± 5.59	98.84 ± 4.70	91.84 ± 4.91	91.29 ± 4.70	89.8 ± 4.82
	0.00	-27.82 ± 2.35	-31.89 ± 2.74	-36.72 ± 3.81	-37.09 ± 3.72	-38.12 ± 3.65
1/4" GH NEON 6.5 (oz)	149.35 ± 12.57	125.15 ± 9.72	115.23 ± 9.80	106.39 ± 9.34	105.44 ± 8.95	103.06 ± 8.68
	0.00	-16.20 ± 3.46*	-22.85 ± 4.06*	-28.77 ± 3.58*	-29.40 ± 3.36*	-30.99 ± 2.84*
5/16" AU NEON 4.5 (oz)	117.33 ± 5.21	87.76 ± 6.45	79.74 ± 6.34	72.73 ± 5.70	72.39 ± 6.75	70.70 ± 6.78
	0.00	-25.20 ± 3.09	-32.04 ± 3.33	-38.01 ± 3.28	-38.29 ± 3.83	-39.74 ± 3.89
5/16" GH NEON 4.5 (oz)	108.29 ± 4.72	82.46 ± 4.38	75.05 ± 4.32	69.88 ± 4.04	69.34 ± 4.17	67.91 ± 4.24
	0.00	-23.85 ± 3.59	-30.69 ± 3.87	-35.47 ± 3.37	-35.97 ± 3.59	-37.29 ± 3.95
5/16" AO NEON 4.5 (oz)	134.73 ± 17.84	103.4 ± 9.18	94.22 ± 9.08	88.37 ± 8.85	85.59 ± 9.34	82.05 ± 8.50
	0.00	-23.25 ± 6.87	-30.07 ± 6.25	-34.41 ± 6.25	-36.48 ± 6.05	-39.10 ± 5.64
5/16" GH NEON 6.5 (oz)	133.99 ± 7.10	122.43 ± 8.38	112.23 ± 9.06	105.71 ± 8.91	103.87 ± 8.91	100.27 ± 9.42
	0.00	-8.62 ± 2.66*	-16.23 ± 3.62*	-21.10 ± 3.48*	-22.47 ± 3.39*	-25.16 ± 3.63*

Note. Values are mean (gf) ± standard deviation.

*Denote statistical significance in percentage of force degradation between 4.5 ounces and 6.5 ounces colored-latex elastics ($p < 0.001$).

Force Degradation

After immersion, the elastics showed visible color changes and swelling. Force degradation followed a non-linear pattern, with a steep decline

during the first hour and a gradual reduction thereafter (Figures 2–4). All groups demonstrated progressive force loss at 1, 3, 6, 12, and 24 hours (Table II).



Figure 1 Elastics were mounted between stainless steel pins on acrylic boards at fixed extensions three times the lumen diameter.

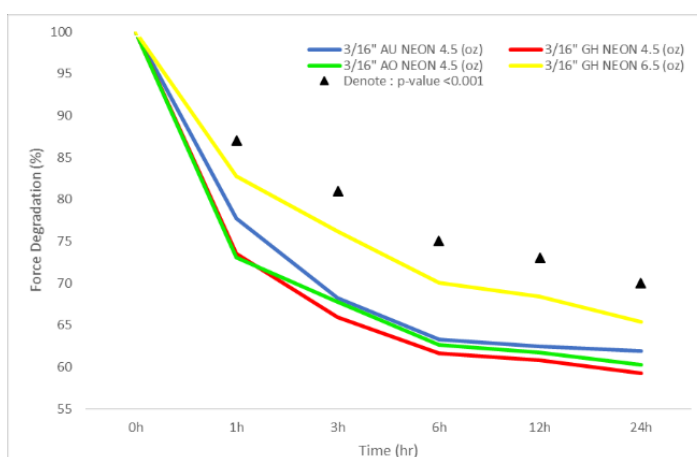


Figure 2 Force degradation (%) over time (hours) of 3/16" colored elastics.
 ▲ Denotes an average difference in percentage of force degradation statistically significant ($p < 0.001$).

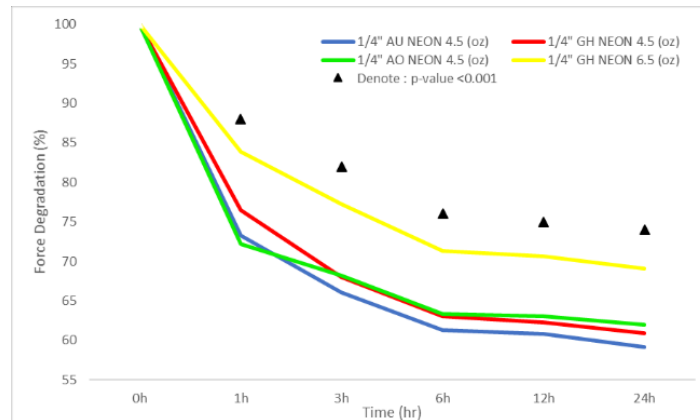


Figure 3 Force degradation (%) over time (hours) of 1/4" colored elastics.

▲ Denotes an average difference in percentage of force degradation statistically significant ($p < 0.001$).

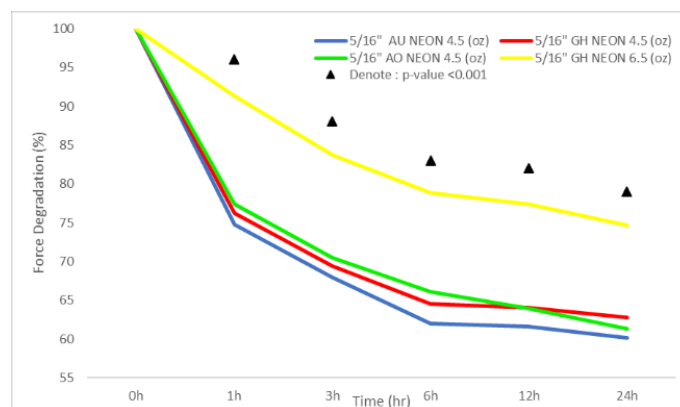


Figure 4 Force degradation (%) over time (hours) of 5/16" colored elastics.

▲ Denotes an average difference in percentage of force degradation statistically significant ($p < 0.001$).

For 3/16-inch elastics, residual force in the 4.5-oz group decreased to 74.80%, 67.31%, 62.53%, 61.65%, and 60.49% across time points, while the 6.5-oz group retained higher values (82.76% to 65.39%). Similar patterns were observed in 1/4-inch elastics, with 4.5-oz groups declining to 60.69% and 6.5-oz groups to 69.05% after 24 hours. For 5/16-inch elastics, residual forces were 61.43% (4.5-oz) and 74.71% (6.5-oz) at 24 hours.

The greatest degradation occurred in 3/16-inch G&H Neon 4.5-oz elastics (-26.50% at 1 hour, -40.81% at 24 hours) and 1/4-inch AU Neon 4.5-oz elastics (-26.65% at 1 hour, -40.82% at 24 hours). The smallest degradation was seen in 5/16-inch G&H Neon 6.5-oz elastics (-8.62% at 1 hour, -25.16% at 24 hours).

At all-time points, repeated measures ANOVA revealed a significant difference between force levels. Bonferroni post hoc testing showed that the 6.5 force produced significantly higher values than the 4.5 force (mean difference = -8.596, $p < 0.001$). In other words, 6.5-oz elastics exhibited significantly lower percentages of force loss than 4.5-oz elastics ($p < 0.001$). No significant differences were found among manufacturers for elastics with equivalent 4.5-oz forces ($p > 0.05$). Overall, after 24 hours, 6.5-oz elastics retained 69.71% of initial force compared with 60.87% for 4.5-oz elastics ($p < 0.001$).

Repeated-measures ANOVA suggests significant differences across the six time points. Post hoc pairwise comparisons with Bonferroni adjustment showed that values at 0 hours were markedly lower than those at all subsequent time points (mean differences ~22–37; $p < 0.001$). Between 1 and 3–24 hours, significant increases were observed (mean differences ~6.8–14.6; $p < 0.001$). Comparisons of 3 hours with 6–24 hours revealed smaller but still statistically significant differences (mean differences ~5.2–7.8; $p < 0.001$). From 6 to 12–24 hours, differences were modest yet significant (mean differences ~0.9–2.6; $p < 0.001$). Finally, a small but significant difference was detected between 12 and 24 hours (mean difference ~1.7; $p < 0.001$). All comparisons remained significant at the 0.05 level after Bonferroni correction, indicating that each successive time point differed significantly from the previous one, although the magnitude of difference progressively decreased over time (Table 3).

Declared force of the elastics demonstrated a statistically significant moderate-to-strong positive correlation with the amount of force loss at all evaluated time intervals (Spearman's $r = 0.607$ – 0.657 , $p < 0.001$). In contrast, elastic size showed a statistically significant weak negative correlation with the percentage of force degradation across the same time intervals (Spearman's $r = -0.204$ to -0.243 , $p < 0.001$). Spearman's correlation coefficients and their corresponding significance levels for all time intervals are presented in Table 4. No statistically significant correlation was found between declared force and elastic size in this study ($p > 0.330$).

Discussion

Fifteen samples of each elastic type were tested, consistent with previous studies [3,11]. Elastic force is typically assessed at three times the lumen diameter, known as the “standard force index” or “rule of three” [12,13]. Some investigations, however, reported that declared forces may be achieved only twice the lumen diameter [14]. In this study, elastics were stretched at standardized intervals to ensure accurate force assessment.

Intermaxillary elastics remain essential orthodontic auxiliaries, though their mechanical properties vary between latex and non-latex types. Non-latex elastics generally show greater force degradation [15,16], while one study found latex elastics delivered higher forces but degraded more rapidly than latex-free types [5]. Clinicians should therefore consider both the patient's medical history and elastic properties when selecting materials. A discrepancy exceeding 10% between declared and measured force has been suggested to have clinical significance [17].

Table 3 Pairwise comparisons of Bonferroni Post Hoc.

(I) factor1	(J) factor1	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
1	2	22.272 [*]	.480	.000	20.844	23.700
	3	29.108 [*]	.478	.000	27.685	30.532
	4	34.325 [*]	.455	.000	32.972	35.678
	5	35.223 [*]	.441	.000	33.911	36.535
	6	36.921 [*]	.423	.000	35.662	38.180
2	1	-22.272 [*]	.480	.000	-23.700	-20.844
	3	6.836 [*]	.171	.000	6.327	7.345
	4	12.052 [*]	.208	.000	11.433	12.672
	5	12.951 [*]	.220	.000	12.297	13.604
	6	14.649 [*]	.257	.000	13.884	15.414
3	1	-29.108 [*]	.478	.000	-30.532	-27.685
	2	-6.836 [*]	.171	.000	-7.345	-6.327
	4	5.216 [*]	.151	.000	4.766	5.667
	5	6.115 [*]	.171	.000	5.606	6.623
	6	7.813 [*]	.231	.000	7.125	8.501
4	1	-34.325 [*]	.455	.000	-35.678	-32.972
	2	-12.052 [*]	.208	.000	-12.672	-11.433
	3	-5.216 [*]	.151	.000	-5.667	-4.766
	5	.898 [*]	.083	.000	.651	1.145
	6	2.596 [*]	.156	.000	2.133	3.059
5	1	-35.223 [*]	.441	.000	-36.535	-33.911
	2	-12.951 [*]	.220	.000	-13.604	-12.297
	3	-6.115 [*]	.171	.000	-6.623	-5.606
	4	-.898 [*]	.083	.000	-1.145	-.651
	6	1.698 [*]	.127	.000	1.320	2.076
6	1	-36.921 [*]	.423	.000	-38.180	-35.662
	2	-14.649 [*]	.257	.000	-15.414	-13.884
	3	-7.813 [*]	.231	.000	-8.501	-7.125
	4	-2.596 [*]	.156	.000	-3.059	-2.133
	5	-1.698 [*]	.127	.000	-2.076	-1.320

*Denote the mean difference is significant at the 0.05 level. b. Adjustment for multiple comparisons: Bonferroni.

Table 4 Spearman's Correlation Coefficient (rho) values between the force loss at the different time intervals and the force and size of the elastics.

Time interval (h)	Size	Force
0	-0.243**	0.657**
1	-0.204**	0.637**
3	-0.220**	0.619**
6	-0.225**	0.606**
12	-0.228**	0.611**
24	-0.223**	0.607**

** Correlation is significant at the 0.01 level (2-tailed).

Colored elastics have gained popularity, particularly among younger patients [2,6,9]. Previous studies noted age-related preferences, with younger patients favoring bright colors and older patients preferring less noticeable options [2,5]. While one study conducted to compare the means of color change found that green elastic showed the least color change, whereas red elastic showed the highest color change, these color changes were not statistically significant [10]. Despite their popularity, the present study revealed substantial variability in initial forces among elastics labeled with identical lumen sizes and declared force values. For example, 4.5 oz elastics ranged from 90.75 to 173.35 gf, while 6.5 oz elastics ranged from 121.07 to 180.49 gf. The absence of standardized labeling—reported variously in grams, gram force, newtons, or ounces—may contribute to clinical confusion.

Consistent with earlier reports, this study confirmed significant force decay over time, characterized by rapid initial loss followed by gradual decline [18,19]. Previous investigations found latex elastics lose 3–25% of force in dry conditions within 24 hours [12,14], and 11–32% under wet oral conditions [6,14]. Similar patterns were observed here, with variability across manufacturers and occasional outliers that may

deliver forces outside the optimal range for tooth movement. To minimize bias, elastics were sourced within two weeks of testing, manufactured within two months, and stored under controlled conditions. Multiple production batches were included to account for manufacturing variability.

This study confirmed significant variability in the initial forces of colored intermaxillary latex elastics, even among products with identical lumen sizes and declared force values. While some elastics closely matched manufacturers' specifications, most deviated substantially, with 6.5 oz elastics showing greater variability than 4.5 oz elastics. Overall, standard force–extension indices ranged from -34.30% to +13.77%, highlighting inconsistency across manufacturers.

Clinically, both initial force and degradation rate are critical, yet manufacturers provide no information on force relaxation. In this study, 6.5 oz elastics retained 69.71% of initial force after 24 hours, compared with 60.87% for 4.5 oz elastics ($p < 0.001$). The greatest force loss occurred within the first hour (8.62–27.82%), followed by a slower decline, consistent with previous reports [3,18,20]. Despite differences in initial force, degradation patterns were similar across manufacturers, supporting earlier findings that initial force magnitude does not predict degradation rate [21–23].

Even though an in vitro study cannot fully replicate actual clinical conditions, the findings of the present investigation provide clinically relevant information for selecting colored intermaxillary elastics and controlling force delivery in practice. Nevertheless, further studies are needed to validate these results under dynamic intraoral conditions, to compare products across different manufacturers, and to examine patient-related factors such as color preferences and compliance. Such investigations would strengthen the evidence base and help clinicians balance mechanical performance with patient motivation during orthodontic treatment. Compared with in vivo studies, the present results showed greater force loss under controlled in vitro conditions. Prior investigations reported 17–32% degradation at 24 hours [24–26], whereas this study found losses approaching 40%. Despite the extensive use of colored intermaxillary elastics, the force extension during their clinical administration and force degradation in vivo remains unestablished [27]. However, an in vitro study cannot fully replicate actual clinical conditions; the findings of the present investigation provide clinically relevant information for selecting colored intermaxillary elastics and controlling force delivery in practice [28]. Such discrepancies may reflect the absence of cyclic loading, saliva, and other intraoral factors and the impact of different elastic traction methods [29].

A repeated-measures ANOVA demonstrated a significant effect of time on the measured variable, $p < 0.001$. Post hoc pairwise comparisons with Bonferroni adjustment revealed that each successive time point differed significantly from the preceding one. Specifically, the largest differences were observed between the initial measurement (0h) and all subsequent time points (mean differences ranging from 22.27 to 36.92, all $p < 0.001$). Moderate differences were found

between 1h and later measurements (mean differences 6.84–14.65, all $p < 0.001$), while smaller but statistically significant differences were noted between 3h and 6h–24h (mean differences 5.22–7.81, all $p < 0.001$). Even the final comparisons (6h vs. 12h, 12h vs. 24h, and 6h vs. 24h) showed small but significant differences (mean differences 0.90–2.60, all $p < 0.001$). These findings indicate a progressive change across time points, with the magnitude of difference decreasing over successive intervals, suggesting that the majority of change occurred early and was followed by smaller but consistent adjustments. Correlation analysis revealed that force loss was more strongly associated with declared force level than elastic size. A moderate positive correlation ($\rho = 0.606$ – 0.657 , $p < 0.01$) indicated that elastics with higher force levels tended to lose more force over time. In contrast, elastic size showed a weak negative correlation ($\rho = -0.204$ to -0.243 , $p < 0.01$), suggesting larger elastics degraded less. These findings emphasize the importance of considering both force level and size when selecting elastics for clinical use.

This study has several limitations. First, the investigation was conducted in vitro under static traction conditions, which did not fully replicate the dynamic clinical oral environment. Second, elastics were tested in batches of 15 and measured sequentially, introducing a time lag between the first and last specimens that may have influenced the results. Finally, only 6.5-oz elastics from G&H Orthodontics® were evaluated, with three lumen diameters (3/16, 1/4, and 5/16 in), due to supplier availability constraints. This asymmetry restricts inter-manufacturer comparisons at higher force levels and the generalizability of conclusions regarding 6.5 oz elastics. Therefore, future studies should incorporate pre-stretching, cyclic loading, cyclic stretching speed, oral temperature, salivary pH, artificial saliva, jaw movement, dietary influences,

storage temperature, and potential effects of radiofrequency electromagnetic radiation to better replicate clinical conditions [10,11].

Conclusion

This in vitro study revealed significant discrepancies between manufacturers' declared forces and the actual initial forces of colored intermaxillary latex elastics tested at three times the lumen diameter. Elastics labeled as 6.5 oz delivered substantially lower initial forces and showed poor conformity with the standard force-extension index, whereas 4.5 oz elastics were closer to specifications.

All elastics exhibited marked force degradation under simulated oral conditions, with the greatest loss occurring within the first hour, followed by a gradual decline. After 24 hours, 6.5 oz elastics retained approximately 69.7% of their initial force compared with 60.9% for 4.5 oz elastics ($p < 0.001$). Correlation analysis indicated that force loss was more strongly associated with declared force level than elastic size, with larger elastics showing slightly reduced degradation.

Clinically, the variability in initial force and pronounced early decay highlight the need for careful elastic selection and frequent replacement. To maintain continuous and effective orthodontic force delivery, colored latex elastics should be replaced regularly, particularly during the early phase of use.

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Disclosure statement

The authors have no conflicts of interest

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