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Force of Intermaxillary Latex Elastics from Different Suppliers: A Comparative In Vitro Study

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Abstract: The main characteristic of orthodontic intermaxillary elastics is the generated force. Therefore, it is necessary to know the exact properties of elastics for clinical use and their force degradation over time. Methods: A total of 500 latex elastics of the type 3/16″ Medium from the manufacturers Dentaurum, American Orthodontics, 3M, Ortho Organizers, and G&H Orthodontics were tested; 100 elastics from each. The force was measured with a force meter at time 0 and at 2, 8, 24, and 48 h. Elastics were stored being stretched three times on a 3D-printed board in an incubator at 37 °C and under controlled humidity. Shapiro–Wilk normality tests, ANOVA tests, and Bonferroni post hoc tests were used. Results: The mean initial force among the manufacturers ranged from 1.109 N to 1.550 N, with Dentaurum elastics being the closest to the declared force of 1.255 newton. The greatest force degradation occurred during the first two hours; the decrease in force within 24 h ranged from 20% to 33% among the manufacturers. The maximum decrease was observed for American Orthodontics elastics. The smallest decrease occurred between 2 and 8 h for 3M, and between 24 and 48 h for Ortho Organizers. Conclusion: Intermaxillary 3/16″ Medium elastics measured in vitro differ in initial force and force degradation among individual manufacturers. The attending clinician must be aware of the basic parameters of the elastics when recommending them to patients, and measuring the initial force directly in the patient's mouth with a force meter might be helpful.

Keywords: intermaxillary elastics; initial force; force degradation

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1. Introduction

Intermaxillary elastics have become an integral part of treatment with fixed orthodontic appliances, aligners, and a combined orthodontic–surgical approach. When indicated appropriately and with good patient compliance, they can reduce the duration and increase the efficacy of ongoing orthodontic treatment. Elastics can be used along with an orthodontic appliance within one dental arch, in an intermaxillary manner between the upper and lower dental arches, or can be attached to intraoral as well as extraoral auxiliary appliances [1,2]. According to the material used, elastics can be divided into latex elastics and nonlatex elastics; they can be further divided based on their size and thickness [3]. The manufacturers declare that the desired force should be achieved when each elastic is stretched to three times its diameter [4–6]. The clinician chooses an adequate size and thickness of the elastic to achieve the optimal force and desired therapeutic effects.

It is important that each of the elastics used meet the criteria and produce the desired force for as long as possible while worn by the patient. Elastics are known to undergo force degradation that gradually decreases during wear [7,8]. Therefore, clinicians typically advise patients to replace their elastics every 8 h, or after 12 or 24 h; however, clear guidelines for the timing of replacing elastics are lacking.

Previous studies dealing with elastics have evaluated in detail force degradation in vitro and/or in vivo; however, they largely utilized a small sample of elastics of the order of dozens of elastics evaluated from each brand [5,7,9] and used elastics of one batch. The results may have been biased due to the use of a relatively small number of elastics from a single package.

The most widely used size of elastics in clinical practice is 3/16“ Medium latex elastics (4.8 mm in diameter), which when stretched to three times their size should correspond to a force of 4.5 oz ≈ 127.6 g (1.3 N). They have also been shown to be the most reliable in terms of applied force with respect to the declared force, and in terms of force degradation [10]. In addition, Kanchana et al. [11] reported that 3/16“ Medium elastics were more homogeneous and showed less variation within the sample in comparison with their light and heavy counterparts. The present paper reports the values of the initial force of 3/16“ Medium elastics from five different manufacturers and five different packages of various batches; the degradation of force after 2, 8, 24, and 48 h; and the nature of the course of this force degradation.

2. Materials and Methods

Five hundred intermaxillary elastics were measured in vitro five times: at time 0, and at 2 h, 8 h, 24 h, and 48 h. The elastics were obtained from five manufacturers: Dentaurum® (Dentaurum, Ispringen, Germany), American Orthodontics® (American Orthodontics Corporate, Sheboygan, WI, USA), 3M® (3M, Monrovia, CA, USA), Ortho Organizers® (Ortho Organizers, Carlsbad, CA, USA), and G&H Orthodontics® (GH Orthodontics, Franklin, TN, USA). One hundred elastics from each manufacturer were analyzed from five different batches of packaging, containing 20 pieces each. A total of 2500 measurements were made. All elastics were within their use-by date, delivered by the manufacturer no later than two weeks prior to the measurement, manufactured no later than two months prior to the measurement, and, after being received from the manufacturer, stored in sealed plastic containers in a dark environment. All elastics were subjected to “prestretching” immediately before the actual measurement—they were stretched to three times the original resting diameter, according to the recommendations by Proffit and Liu [4,12].

The force of the elastics was measured one by one with a force meter from the company “ScienceCube” set to the exact distance for each manufacturer, calibrated before each set of measurements. The force meter was connected to the portable data logger “LabQuest3” from the Vernier company (Figure 1). The measurements were repeated after 2, 8, 24, and 48 h and the results were recorded in newtons.

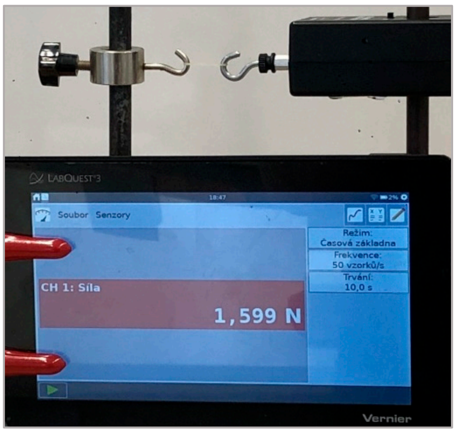

Figure 1. Elastic stretched to the exact distance on the force meter “ScienceCube” connected to the portable data logger “LabQuest3”.

To standardize the stretching conditions between measurements, a 3D model of a board with spurs was created in the “Rhinoceros 3D” program and subsequently printed using the “Prusa i3 MKS+” printer. The distances between spurs corresponded to the differences in the diameters of elastics from individual manufacturers (Figure 2), with five elastics from one manufacturer being subjected to the experiment each time. The simulation of the oral environment in the laboratory was made possible using the Ivoclar Vivadent Cultura incubator at a constant temperature of 37 °C and in a controlled-humidity environment, where the stretched elastics were stored in between the measurements. The conditions in the incubator were continuously monitored using a precision thermometer and a humidity sensor.

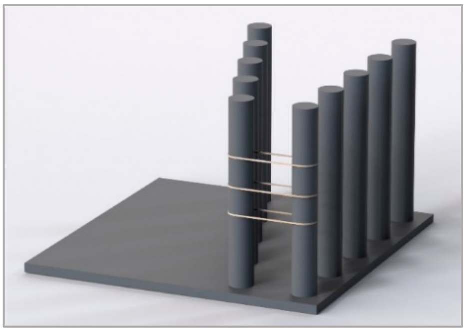

Figure 2. Three-dimensional model of a board with spurs for the standardization of the elastic stretch.

The collected data were analyzed by Shapiro–Wilk normality tests, which showed that the force distribution was normal in elastics from most manufacturers; there was a normality issue only in the 3M group, in which extreme values were measured. Further statistical processing was performed using parametric methods, which were validated with nonparametric tests. A comparison of the five independent groups was conducted using the analysis of variance (ANOVA) with subsequent Bonferroni post hoc tests. ANOVA evaluated the variation of forces generated at all selected times. A p-value of less than 0.05 was considered statistically significant. For a better understanding of the results they were converted from newtons to grams and ounces using the following formula: 1 N = 101.9716212978 gf (gram force); 1 oz = 28.3495231 g.

3. Results

3.1. Initial Force

The mean values of the initial force, as well as the force level declared by the manufacturer, the diameter, the stretching length, and the force variance, are all shown in Table 1. The mean values of initial force converted to grams and ounces are displayed in Tables 2 and 3.

Table 1. Mean initial forces measured for elastics from five manufacturers. The diameter and declared force given by the manufacturer, and the standard deviation, variance, minimal, and maximal values are displayed in the table. "Stretching 3 times" represents the length of elastic stretch.

Manufacturer	Diameter (mm)	Stretching 3 Times (mm)	Declared Force (N)	Mean Initial Force (N)	Force Difference (N)	SD	Variance	Minimum	Maximum
Dent	4.8	14.4	1.255	1.301	0.046	0.222	0.049	0.860	1.990
AO	4.8	14.4	1.255	1.109	−0.146	0.093	0.009	0.870	1.370
3M	4.6	13.8	1.108	1.406	0.298	0.329	0.108	0.910	2.500
OO	4.8	14.4	1.251	1.550	0.299	0.218	0.047	1.100	2.060
G&H	4.7	14.1	1.251	1.124	−0.127	0.145	0.021	0.790	1.510

mm = millimeter; N = newton; SD = standard deviation; Dent = Dentaurum; AO = American Orthodontics; OO = Ortho Organizers; G&H = G&H Orthodontics.

Table 2. Mean initial forces in newtons and force degradation in percent at 2, 8, 24, and 48 h.

Hours	Manufacturer	Mean Initial Force (N)	SD	Variance	Minimum	Maximum	p
0	Dent	1.301	0.222	0.049	0.860	1.990	<0.0001
	AO	1.109	0.093	0.009	0.870	1.370	
	3M	1.406	0.329	0.108	0.910	2.500	
	OO	1.550	0.218	0.047	1.100	2.060	
	G&H	1.124	0.145	0.021	0.790	1.510	
Hours	**Manufacturer**	**Force degradation (%)**	**SD**	**Variance**	**Minimum**	**Maximum**	***p***
2	Dent	16.38	7.82	61.10	−2.15	38.14	<0.0001
	AO	18.76	8.31	69.04	−6.19	42.98	
	3M	10.05	4.45	19.82	−4.46	20.69	
	OO	11.74	4.49	20.12	5.11	26.56	
	G&H	17.74	7.05	49.75	−0.94	35.14	
8	Dent	22.83	8.37	70.00	1.94	44.76	<0.0001
	AO	27.88	9.30	86.40	7.44	51.75	
	3M	14.90	6.32	39.97	−17.56	30.26	
	OO	16.25	5.15	26.54	4.79	30.05	
	G&H	22.24	6.32	39.93	10.58	37.11	
24	Dent	28.32	7.73	59.74	9.71	47.10	<0.0001
	AO	33.20	9.52	90.60	13.08	54.89	
	3M	20.43	6.25	39.03	5.60	39.67	
	OO	19.62	5.85	34.21	4.73	33.00	
	G&H	25.58	6.29	39.63	12.24	43.30	
48	Dent	30.78	7.91	62.63	11.83	47.74	<0.0001
	AO	36.08	9.89	97.88	14.55	61.65	
	3M	24.79	7.63	58.29	6.40	45.80	
	OO	21.23	6.06	36.75	3.38	35.82	
	G&H	27.49	6.56	43.09	12.63	45.36	

N = newton; SD = standard deviation; Dent = Dentaurum; AO = American Orthodontics; OO = Ortho Organizers; G&H = G&H Orthodontics.

The measured initial force of the elastics significantly differed among individual manufacturers ($p < 0.001$). The force declared by the manufacturer Dentaurum was 1.255 N, while the initial force measured was 1.301 N. These elastics most closely approached the declared value, with a difference of 0.046 N. The highest mean value of the initial force of 1.550 N was measured for the manufacturer Ortho Organizers, which also had the greatest difference 0.299 N between the declared force of 1.251 N and the measured initial force. The elastics from 3M had an initial force of 1.406 N, while the declared force was 1.108 N. The lowest force of 1.109 N was measured in the elastics from American Orthodontics along with the value for G&H Orthodontics of 1.124 N, which had a declared force level greater than the one measured with a negative difference (−0.146 N and −0.127 N, respectively).

The greatest variance in the initial force values measured was found for 3M (variance 0.108). Moreover, outliers and extreme values occurred among the 100 elastics measured. The force distribution in the elastics from this manufacturer was not normal given the extreme values measured (Figure 3). Outliers also occurred with other manufacturers, but there were no extreme values, the distribution was normal, and the values of variation were lower (American Orthodontics = 0.009; G&H Orthodontics = 0.021; Ortho Organizers = 0.047; Dentaurum = 0.049).

Table 3. Initial forces at 0 h in newtons, grams, and ounces calculated using the following formula: 1 N = 101.9716212978 gf (gram force); 1 oz = 28.3495231 g. Force degradation at 2, 8, 24, and 48 h is shown as a percentage of the initial force, in newtons, grams, and ounces. Residual force at 2, 8, 24, and 48 h is displayed in newtons, grams, and ounces.

Hours	Manufacturer	Mean Initial Force (N)				Mean Initial Force (g)		Mean Initial Force (oz)
0	Dent	1.301				132.665		4.68
	AO	1.109				113.087		3.989
	3M	1.406				143.372		5.057
	OO	1.55				158.056		5.575
	G&H	1.124				114.616		4.043
	Mean	1.298				132.359		4.669
Hours	**Manufacturer**	**Degradation (%)**	**Degradation (N)**	**Residual force (N)**	**Degradation (g)**	**Residual Force (g)**	**Degradation (oz)**	**Residual Force (oz)**
2	Dent	16.38	0.213	1.088	21.731	110.935	0.767	3.913
	AO	18.76	0.208	0.901	21.215	91.871	0.748	3.241
	3M	10.05	0.141	1.265	14.409	128.963	0.508	4.549
	OO	11.74	0.182	1.368	18.556	139.500	0.655	4.921
	G&H	17.74	0.199	0.925	20.333	94.283	0.717	3.326
	Mean	14.93	0.189	1.109	19.249	113.111	0.679	3.990
8	Dent	22.83	0.297	1.004	30.287	102.378	1.068	3.611
	AO	27.88	0.309	0.800	31.529	81.558	1.112	2.877
	3M	14.9	0.209	1.197	21.362	122.010	0.754	4.304
	OO	16.25	0.252	1.298	25.684	132.372	0.906	4.669
	G&H	22.24	0.250	0.874	25.491	89.125	0.899	3.144
	Mean	20.82	0.264	1.034	26.871	105.489	0.948	3.721
24	Dent	28.32	0.368	0.933	37.571	95.094	1.325	3.354
	AO	33.2	0.368	0.741	37.545	75.542	1.324	2.665
	3M	20.43	0.287	1.119	29.291	114.081	1.033	4.024
	OO	19.62	0.304	1.246	31.011	127.045	1.094	4.481
	G&H	25.58	0.288	0.836	29.319	85.297	1.034	3.009
	Mean	25.430	0.323	0.975	32.947	99.412	1.162	3.507
48	Dent	30.78	0.400	0.901	40.834	91.831	1.440	3.239
	AO	36.08	0.400	0.709	40.802	72.285	1.439	2.550
	3M	24.79	0.349	1.057	35.542	107.830	1.254	3.804
	OO	21.23	0.329	1.221	33.555	124.501	1.184	4.392
	G&H	27.49	0.309	0.815	31.508	83.108	1.111	2.932
	Mean	28.074	0.357	0.941	36.448	95.911	1.286	3.383

N = newton; g = gram; oz = ounce; Dent = Dentaurum; AO = American Orthodontics; OO = Ortho Organizers; G&H = G&H Orthodontics; Mean = average calculated by dividing the sum of the five values in the set by their number.

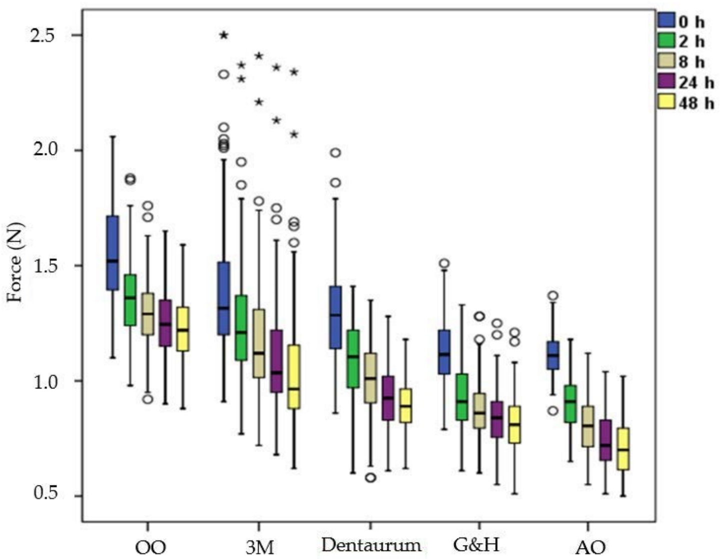

Figure 3. Box graph showing median, 1st quartile, and 3rd quartile force values for all five manufacturers measured at all time periods; ° = outliers; * = extreme values; h = hours; N = newton. AO = American Orthodontics; OO = Ortho Organizers; G&H = G&H Orthodontics.

3.2. Force Degradation

Force degradation in intermaxillary elastics was not linear over time, with the greatest drop occurring for all manufacturers within the first two hours (Figures 3 and 4; Tables 2 and 3). The force values at 2, 8, 24, and 48 h decreased gradually for all companies, with the mean decrease being 14.9%, 20.8%, 25.43%, and 28.1%, respectively. At all time periods, the rate of force degradation was different among the manufacturers ($p < 0.0001$). The greatest force degradation occurred in the elastics from American Orthodontics: a drop by 18.94% at 2 h to 81.06% of the initial force. At 8 h, the force measured decreased by 27.95% versus the initial force, and continued to decrease: at 24 h, a drop by 33.36% was measured, and at 48 h, there was a drop by 36.25% of the initial force. At 48 h, the elastics from American Orthodontics had 63.75% of their initial force, i.e., 0.707 N from the original 1.109 N. The smallest force degradation occurred in the elastics from 3M at 2 and 8 h; at 2 h, there was a drop by 10.24%, and at 8 h it was 15.08%. Subsequently, however, this increased to 20.41% and 24.61% at 24 h and 48 h, respectively. At 24 h and 48 h, force degradation was smallest for Ortho Organizers, with values of 20% and 21.61%, respectively; as a result, the residual force at 48 h was the greatest, at 78.39%. Force degradation for G&H Orthodontics and Dentaurum ranged somewhere in the middle of this interval, and there was a drop to 72.33% and 68.49% of the initial force at 24 h (Table 3). The degradation of forces measured after 2 h was similar in the elastics from G&H Orthodontics and American Orthodontics ($p = 1.0000$); the force degradation measured for the other three companies in the same time period and at 8, 24, and 48 h differed significantly among all manufacturers ($p < 0.0001$) (Table 4).

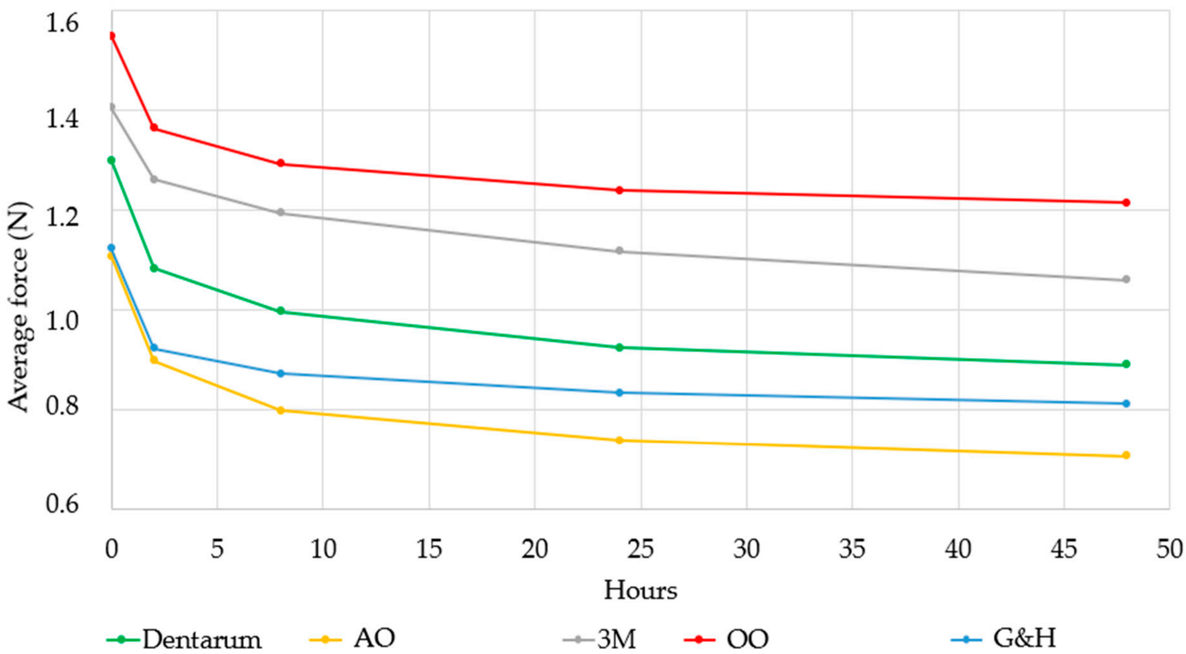

Figure 4. Graph showing the force decrease in five manufacturers at 0, 2, 8, 24, and 48 h. N = newton; AO = American Orthodontics; OO = Ortho Organizers; G&H = G&H Orthodontics.

Table 4. Multiple comparisons of elastic force among manufacturers at 0, 2, 8, 24, and 48 h.

0 Hours			**2 Hours**			**8 Hours**			**24 Hours**			**48 Hours**		
Mfr.	**DV**	**MD**	**Mfr.**	**DV**	**MD**	**Mfr.**	**DV**	**MD**	**Mfr.**	**DV**	**MD**	**Mfr.**	**DV**	**MD**
Dent	AO	0.192 ***	Dent	AO	0.184 ***	Dent	AO	0.199 ***	Dent	AO	0.186 ***	Dent	AO	0.184 ***
	3M	−0.105 *		3M	−0.178 ***		3M	0.197 ***		3M	−0.194 ***		3M	−0.170 ***
	OO	−0.250 ***		OO	−0.281 ***		OO	0.296 ***		OO	−0.315 ***		OO	−0.325 ***
	G&H	0.177 ***		G&H	0.160 ***		G&H	0.125 ***		G&H	0.090 *		G&H	0.077 *
AO	Dent	−0.192 ***	AO	Dent	−0.184 ***	AO	Dent	0.199 ***	AO	Dent	−0.186 ***	AO	Dent	−0.184 ***
	3M	−0.297 ***		3M	−0.362 ***		3M	0.396 ***		3M	−0.380 ***		3M	−0.353 ***
	OO	−0.441 ***		OO	−0.465 ***		OO	0.495 ***		OO	−0.501 ***		OO	−0.508 ***
	G&H	−0.015		G&H	−0.024		G&H	−0.074 *		G&H	−0.096*		G&H	−0.106 ***
3M	Dent	0.105 ***	3M	Dent	0.178 ***	3M	Dent	0.197 ***	3M	Dent	0.194 ***	3M	Dent	0.170 ***
	AO	0.297 ***		AO	0.362 ***		AO	0.396 ***		AO	0.380 ***		AO	0.353 ***
	OO	−0.144 ***		OO	−0.102 *		OO	−0.099 *		OO	−0.122 ***		OO	−0.155 ***
	G&H	0.282 ***		G&H	0.338 ***		G&H	0.321 ***		G&H	0.284 ***		G&H	0.247 ***
OO	Dent	−0.250 ***	OO	Dent	0.281 ***	OO	Dent	0.296 ***	OO	Dent	0.315 ***	OO	Dent	0.325 ***
	AO	0.441 ***		AO	0.465 ***		AO	0.495 ***		AO	0.501 ***		AO	0.508 ***
	3M	−0.144 ***		3M	0.102 *		3M	0.099 *		3M	0.122 ***		3M	0.155 ***
	G&H	0.427 ***		G&H	0.441 ***		G&H	0.420 ***		G&H	0.405 ***		G&H	0.402 ***
G&H	Dent	0.177 ***	G&H	Dent	−0.160 ***	G&H	Dent	0.125 ***	G&H	Dent	−0.090 *	G&H	Dent	−0.077 *
	AO	−0.015		AO	0.024		AO	0.074 *		AO	0.096 *		AO	0.106 ***
	3M	0.282 ***		3M	−0.338 ***		3M	0.321 ***		3M	−0.284 ***		3M	−0.247 ***
	OO	0.427 ***		OO	−0.441 ***		OO	0.420 ***		OO	−0.405 ***		OO	−0.402 ***

*** = $p < 0.0001$; * = $p \leq 0.005$; Mfr. = manufacturer; DV = dependent variable; MD = mean difference; Dent = Dentaurum; AO = American Orthodontics; OO = Ortho Organizers; G&H = G&H Orthodontics.

4. Discussion

When choosing suitable elastics for the patient, clinicians need to take into consideration that identically labeled intermaxillary 3/16″ Medium differ among manufacturers in terms of both the reported force values and the diameter of the elastics. In our study, the reported forces of the elastics from five different manufacturers ranged from 113 g to 128 g and diameter varied from 4.6 mm to 4.8 mm. Worldwide, there is no current consensus on the marking of the force on the packaging; it can be given in grams (g), newtons (N), or in ounces (oz), which may result in a lack of awareness and confusion for a clinician using a different measurement system. The resulting force designated on the packaging of elastics can be calculated using the following formula: 1 N = 101.9716212978 gf (gram force) $\approx$ 102 g; 1 oz = 28.3495231 g = 28.35 cN (centinewton).

From the clinician's perspective, the choice of an intermaxillary elastic depends on the desired movement of teeth to be achieved, the type of appliance used, and the distance between the insertion points of the elastic, which determine the stretching length of the elastic. The manufacturers, as well as most studies in the literature, report that the declared force is achieved when the elastic is stretched to three times its diameter, which is the value also used in our experiment (rule of "3") [11]. However, there have been studies reporting a stretch of elastics to only twice their diameter to achieve the declared force [13,14]. Nonetheless, the validity of proposals on how much stretch is required from an elastic to obtain the declared force has been seriously questioned and, according to some studies, the force may vary with the size and level of force of the elastics [11,14,15]. Gioka et al. measured the distance of elastic stretch in order to achieve the declared force [5]. They found that, in 3/16″ Medium and Heavy elastics, it was 2.7-fold the diameter. In elastics of other sizes, the stretch ranged from 2.6-fold to 5-fold of the elastic's diameter to achieve the declared force. To avoid the bias created by the differences in diameter, we developed and printed an exact 3D model of a board with spurs in which the spurs for stretching elastics were made at the precise three-fold length of the diameter declared by each manufacturer. The comparison of elastic forces should thus be more accurate than that in studies where all elastics were stretched to the same length [7,9,11,16].

In 1994, Baty et al. [17] reported a possible clinically significant impact when the difference between the measured and the declared force of elastics was more than 10%; however, in the present results, even the initial force differed by more than that from the declared force for most manufacturers. Although the declared initial forces of the 3/16″ Medium did not differ much between the manufacturers, only by 0.147 N, i.e., 15 g, in reality the initial force differed by 0.441 N, i.e., 45 g between the two manufacturers with the lowest and highest force values. For example, the smallest elastics in diameter were the 3M 4.6 mm elastics, which also has the weakest declared initial force, but the measured initial force was the second highest of the five manufacturers. In 2022, Castroflorio et al. [10] also reported differences in the initial forces measured compared with the declared forces for 3/16″ elastics from several manufacturers when stretched to 16.3 mm. Similarly, differences between the measured and declared initial forces were reported in some older studies in smaller samples of elastics [9,12,14]. Additionally, the outliers and extreme values of force that we found among some of the samples of the 100 elastics from each brand might influence the clinical outcome of orthodontic treatment by delivering more force than necessary when worn by the patient. As the value of generated force can be influenced by the age and storage of elastics, all elastics used in the present study were within their use-by date, delivered by the manufacturer no later than two weeks prior to the measurement, manufactured no later than two months prior to the measurement, and stored in dark plastic containers in a dry and cool environment. Twenty elastics from five different production batches from each manufacturer were measured; the reason for this was to reduce the incidence of bias in case a manufacturing problem occurred within a specific batch, or if it was heated during transport.

Clinically, not only is the initial force important, but also the force degradation while wearing the elastics; however, the degradation rates are not reported by any manufacturer. According to our results, on average, a force degradation of 25.43% was found for all five manufacturers at 24 h, with the greatest force degradation occurring within the first two hours (10.05–18.76%), followed by a more gradual decrease. In most other studies, the greatest rate of force degradation was also noted in the first measured interval. Fernandes et al. [9] reported 15.26–20.7% for the American Orthodontics 3/16″ elastics stretched to 30 mm during the first two hours, similar to our findings. Castoflorio et al. [10] measured a force degradation rate of 7.92% in the 3/16″ Medium elastics from the 3M brand stretched to 24.6 mm during the first hour, and Notaroberto et al. [18] reported a force degradation of 14.6% in the same time interval and using the same manufacturer. By contrast, Qodcieh et al. [6] reported a greater force degradation by 26.3 ± 8.6% in the 3/16″ Medium elastics from the 3M brand when stretched to 24.1 mm. Other studies also demonstrated a greater rate of force degradation within the first two hours, being between 25% and 40% [9–11]. Some studies found an even greater rate of force degradation during the first hour [14,18–23], in the first half hour [7,14], and in the first three hours [24]. Hwang and Cha [25] showed that after one day, the force degradation was approximately 23% to 28%. Similar to our findings, there have been studies reporting that, as time progressed, the force degradation became slower with continued stretching for longer periods [9,11,21,26]. In a study by Gioka et al. [5], where forces were measured continuously, the rate of degradation in the first hours of testing was not reported, but it was stated that the greatest rate of force degradation occurred between 3 and 5 h. In our research, continuous data were not collected, and force was recorded periodically at 0, 2, 8, 24, and 48 h in accordance with most studies; however, using noncontinuous data to construct force relaxation curves may have induced some unavoidable approximation.

Force degradation over time differed among individual manufacturers in the present study, as did the values of initial force. The greatest rate of force degradation occurred in the elastics from American Orthodontics, which had 72.3 g of force at 48 h. By contrast, the elastics from Ortho Organizers, whose initial force was highest, exhibited a force after 48 h of 124.5 g, i.e., a value close to the declared initial force. This supports the findings of the study of Hershey and Reynolds, in which the authors reported that initial force had no relationship with the amount of force degradation [27]. By contrast, two older studies by Wong [28] and Taloumis et al. [29] suggested that the greater the initial force of the rubber band, the greater the amount of force degradation.

Despite the extensive use of intermaxillary elastics in orthodontics, the force released during their clinical application and force degradation in vivo remains unclear. In the oral cavity, the characteristics of elastic materials are affected by physical, chemical, and biological factors, some of which are related to functional activities, salivary changes, and nutrition habits; therefore, the results of in vitro and in vivo studies need to be distinguished [7,30–32]. Yang et al. [22] compared in vivo/in vitro force degradation within 48 h for the sizes of 1/8″, 3/16″, $\frac{1}{4}$″, 5/16″, and 3/8″ and the forces of 2 oz and 3.5 oz. During the in vivo research, a group of patients wore clear aligners where the stretching length was precisely defined; this was followed by a comparison of forces in these elastics with those stretched equally in vitro under various laboratory conditions. Under forces of 2 oz and 3 oz, the mean force degradation for $\frac{1}{4}$″ elastics in vivo at 48 h was 33.83% and 36.94%, under in vitro conditions in artificial saliva was 24.60% and 26.89%, and under dry in vitro conditions was 16.44% and 16.21%, respectively. These results imply that force degradation in vivo is much greater than that in vitro. Qodcieh et al. [6] evaluated the 3/16″ Medium elastics from the 3M brand in vivo, stretched to 24.1 ± 4.2 mm with prestretching, and found the following rates of force degradation: 13,4% at 1 h, 15.7% at 3 h, 18.5% at 6 h, 19.9% at 12 h, 22.2% at 18 h, 28.2% at 24 h, and 30.9% at 48 h. In our study, the rates of force degradation in the 3/16″ Medium elastics from the 3M brand stretched to three times the diameter (13.8 mm) were 10.05% at 2 h, 14.9% at 8 h, 20.43% at 24 h, and 24.79% at 48 h, which, in comparison with the above-mentioned in vivo study, are very similar rates of force degradation in vitro with a smaller stretching. The 3/16″ Medium elastics from 3M, stretched to 20 mm under various conditions, were evaluated by Wang [7], who found that at 48 h, the residual elastic force was 61% in vivo, 86% in vitro in a dry environment, and 71% in vitro in artificial saliva, being close to the results regarding the residual force of the 3/16″ Medium elastics from the 3M brand in our study. In the study by Notaroberto et al. [18], who evaluated latex and nonlatex 3/16″ elastics from American Orthodontics in vivo and stretched to 25 mm, the force degradation of 3/16″ latex elastics at 24 h was 19.9%, which is in contrast with our results, where the force degradation in one day was greater than one-fourth of the initial force. Among the limitations of this study are the in vitro design and static stretching of the elastics, which make it impossible to fully reproduce clinical conditions, such as the simulation of the insertion and removal of elastics before and after oral hygiene, the influence of chemical factors from meals and drinks, etc., and which may have significantly influenced the results.

There are different opinions concerning what initial force to choose for elastics in individual patients, as well as in terms of the timing of replacing elastics when worn continuously by patients. As early as 1970, Andreasen and Bishara [21] suggested using 40% more force than optimal at the commencement of elastic application to compensate for the initial loss, as did some later studies [7,14]. In order to maintain the high force of the elastics used, some authors recommend replacing them after 6 h because of force degradation [10], while others advise an interval of 12 h [5]. On the other hand, Gargurde et al. [33] suggested that elastics did not need to be replaced so frequently by patients because, after initial degradation, the force may remain relatively constant for a few days [7,20,21,33,34]. Liu et al. [12] also reported that the force value was remarkably stable after one day because the structural changes caused by repeated stretching were not cumulative. Hixon et al. [24] reported a force degradation of 15% in the first 3 h, followed by a drop of 3% across the next 8 weeks; therefore, they recommend replacing elastics three times a week. However, it has been shown that mechanical damage to elastics can occur after having been worn for several hours [7]; hence, the regular replacement of elastics is essential. Our results, as well as those of most other in vitro or in vivo studies, suggest that elastics lose approximately one-quarter of their strength at 24 h, on average.

It is not only important for practitioners to be familiar with the properties of elastics, but it is also advisable for the manufacturers to display the force degradation of their products because of the differences between different brands of elastics [34]. Because the clinical distance between insertion points varies in individual patients, it is advisable to measure the resulting force with a force meter from one insertion point to another when choosing the appropriate elastics. Clinicians using elastics need to know the force magnitude applied to teeth at a given length of elastic stretch and how this force declines over time to achieve the intended treatment results. Given the great variety of elastics and differences in labeling among manufacturers, it would be advisable for all elastics to be labeled clearly and uniformly; it would also be reasonable to give the diameter in millimeters and the initial force in grams, newtons, and ounces.

5. Conclusions

Elastics labeled as 3/16″ Medium differ among the manufacturers in terms of their diameter, the declared force, and the actually achieved initial force. The attending clinician must be aware of the basic parameters of the elastics when indicating them in individual cases. Measuring the force directly in the patient's mouth with a force meter from one insertion point to another might be advisable to find the magnitude of the initially applied force. The results of 2500 in vitro measurements have shown that there was a loss of an approximately 25% in the force within 24 h; these values differed between individual manufacturers. Measured in vitro, the elastics that most closely approached the value of initial force declared by the manufacturer were those from Dentaurum, while the smallest force degradation occurred in the elastics from 3M at 2 and 8 h and from Ortho Organizers at 24 and 48 h. To gain a better understanding of the elastic's properties, it is necessary in future experiments to focus on the analysis of sufficiently large samples under clearly defined conditions for stretching of the most widely used intermaxillary elastics.

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