Force decay of orthodontic elastomeric chains by using three different mechanisms simulating canine retraction

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ABSTRACT

Background: The ideal force-delivery system must: provide optimal tooth moving forces that elicit the desired effects, be comfortable and hygienic for the patient, require minimal operator manipulation and patient cooperation and provide rapid tooth movement with minimal mobility during orthodontic therapy, the elastomeric chains have the greatest potential to fulfill these requirements.

Materials and Methods: This in vitro study was designed to determine the effect of three different mechanisms for canine retraction : (6-3 , 6-5-3 and chain loop) on the load relaxation behavior of three types of elastomeric chains : (maximum clear , maximum silver and extreme silver) from the same company (Ortho Technology company) with two different brand configurations: closed loop and open (short filament) chains under effect of time at (zero time, 24hr., 7, 14 , 21 and 28 days) in artificial saliva.

Results: Statistical analysis showed that there was a highly significant difference in the mean percentage force decay for the three different mechanisms (P≤ 0.001).For all the three types, the 6-3 mechanism had the smallest mean percentage force decay. There was a highly significant difference in the mean percentage force decay for the different types (P≤ 0.001). For all three mechanisms, extreme silver elastomeric chains had the smallest percentage force decay while maximum silver elastomeric chains had the highest percentage force decay.

Conclusion: This study illustrated that for all the three types of elastomeric chains, the (6-3) mechanism had the smallest mean percentage force decay. This finding suggests that it may be most efficient to retract a canine utilizing elastomeric chain directly from the molar hook to the canine bracket. The chain loop mechanism may not be indicated for space closure in vivo due to the excessive physiological force values involved with this mechanism.

Key words: Force decay of orthodontic elastomeric chains by using three different echanisms simulating canine retraction. (J Bagh Coll Dentistry 2013; 25(1):159-163).

INTRODUCTION

Orthodontic elastomeric chains are polyurethanes, thermosetting polymer products of a step-reaction polymerization process .They were fabricated either by die cut stamping or injection molding and could be poly (ether) urethane or poly (ester) urethane [1, 2].

Elastomeric chains were introduced to the dental profession in the 1960s and have since been used extensively in orthodontic for canine retraction, closing diastemas, correcting rotations shifting midlines, and in achieving general space closure. Elastomeric chains have the advantages of being inexpensive, easily applied and requiring little patient cooperation; however, a disadvantage is that when exposed to the oral environment, they absorb saliva, permanently stained and become permanently deformed due to a breakdown of internal bonds [3, 4].

One of the major short coming of the elastomeric chains was their inability to maintain delivered force for a significant duration, therefore after placement the elastic chains were to be changed at 3-4 weeks intervals [5, 6].

Since there was usually a relaxation of more than half of the force in the first 24 hour, followed by a gradual additional decline over a 3-weeks period accordingly, an initial force heavier than desired would have to be used if one were to offset the initial relaxation and produce adequate force to move the teeth.

Therefore, elastic chains' forces decay rapidly and so could be characterized better as interrupted rather than continuous [7, 8]. This was to be due to a combination of water that causing the weakening of intermolecular force with the chemical degradation, and tooth movement resulting in decreasing stretch upon the elastomeric chain [9, 10].

Numerous past studies have evaluated the force decay of elastomeric chain materials, at the time of these study rare published studies were found that evaluated the force decay of elastomeric chains as related to the mechanical design employed in canine retraction. Therefore, the objectives of this study were twofold. First, to evaluate the percentage force decay of elastomeric chain products utilizing three different mechanical designs simulating canine retraction. Second, to evaluate the percentage force decay of three types of elastomeric chain products from the same company.

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MATERIALS AND METHODS

Three types of elastomeric chains were selected from Ortho Technology Company:
1. Maximum™ Elastomeric chains clear in color which were subdivided into: closed and short.
2. Maximum™ Elastomeric chains metallic silver in color which were subdivided into: closed and short.
3. Extreme™ Elastomeric Chains metallic silver in color which were subdivided into: closed and short.

Three rectangular acrylic resin jigs of 25x10x1 (cm) of length measurements, were constructed to provide a framework for the three mechanisms simulating canine retraction. Each jig was made of two separated halves of acrylic. On both ends of each jig , a Hyrax rapid palatal expander (Dentarum Company / Germany) was embedded into the acrylic. The acrylic jigs were set up so that three different mechanical designs for canine retraction could be studied. The designs were as follows:

Mechanism one: 6-5-3 – simulated elastomeric chain stretching from the first molar hook, attaching to the second premolar hook and attaching to the canine hook. (Figure 1).

Figure 1: Mechanism one (6-5-3).

Mechanism two: chain loop – simulated elastomeric chain stretching from the first molar hook, looping around the canine hook and attaching back to the molar hook. (Figure 2).

Figure 2: Mechanism two (chain loop).

Mechanism three: 6-3 – simulated elastomeric chain stretching from the first molar hook, attaching to the canine hook. (Figure 3).

Figure 3: Mechanism three (6-3).

The 6-5-3 acrylic jig (Figure 1) consisted of 25 triplets of dental screws (Nordin Company / Switzerland) were embedded in the acrylic. The two most lateral dental screws were spaced 29 mm from each other to act as the midpoint of the first molar tube and the midpoint of the canine bracket for attachment of the elastomeric chains. [11]. The middle screws were representative of second premolars hooks. The distance between the middle screws and the screws that representing the first molar hooks was 8 mm, while the remaining 21 mm represent the distance between the second premolar hook and the canine hook [12]**.** For both mechanism two (chain loop) and mechanism three (6-3) (Figures 2, 3), 25 pairs of dental screws were symmetrically aligned in rows in the separated halves of the acrylic resin jigs, they were spaced 29 mm.

Three hundred sixty specimens were tested for load relaxation. Elastomeric chains with an initial length (19mm) and about 50% extension (29mm) were used for the (6-3) and (6-5-3) mechanisms throughout the study, while for the (chain loop) mechanism the elastomeric chains used were with an initial length (38 mm) and about 50% extension (58 mm).

Throughout the study, the three jigs and the attached elastomeric chains were maintained in an artificial salivary solution and stored in an incubator at a constant temperature of 37ºC to simulate oral conditions.

An electronic force gauge was constructed with an action resembles the instron device. Two hooks made of 1 mm stainless steel wire which was sufficiently stiff to exclude any absorption during testing, one hook was attached to the movable end of the load cell which represents the canine tooth, and the other one was soldered to a vertical stud at 29 mm space which represents the first molar tooth. [11]. Figure(4).

Figure 4: Force gauge.

All the elastomeric chains were measured for their force by the measuring device by stretching the specimens between the two hooks of the force gauge for (6-5-3) and (6-3) mechanisms. For (chain loop) mechanism it was done by attaching one end of the specimen to one hook of the force gauge looping around the other hook and attaching back to the first hook.

Statistical analysis

Data collected analyzed by using relevant soft ware statistical package of Social science (SPSS, Chicago, 111). These data of the delivered forces for all specimens were averaged, and the results were analyzed with the following statistics:

1. Descriptive statistics :(mean of load, mean of the percentage of force decay and their standard deviation).
2. Inferential statistics: (T-test, ANOVA- test and LSD- test).

RESULTS

Different types of the elastomeric chains had different mean load and percentage of force decay over time. (Tables 1, 2).

The statistical analysis indicated that there was a significant interaction between type and mechanism(P= 0.000); therefore, the effect of type on percentage force decay over time must be examined separately for each mechanism and the effect of mechanism on percentage force decay over time must be examined separately for each type . (Table 3).

Differences between Different types of elastomeric chains

A HSD was found in the mean percentage force decay for the different types (P = 0,000). For all three mechanisms, extreme silver had the smallest percentage force decay, maximum clear had the highest initial force values and the maximum silver had the largest percentage force decay. Table (3).

Differences between Different mechanisms of canine retraction

There was a HSD in the mean percentage force decay for the different mechanisms (P = 0.000). For all types, the (6-3) mechanism had the smallest mean percentage force decay followed by the (chain loop) mechanism, while the (6-5-3) mechanism had the largest percentage force decay. Table (3).

Table 1: Descriptive data of the mean load (gm) of the elastomeric chains at different test periods and mechanisms.

Days	Type		Mechanism					
			6-3		6-5-3		Chain loop	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
0	Maximum clear	Short	341.07	10.9	339.17	12.2	481.41	3.60
		Closed	129.84	7.06	365.86	10.5	493.70	4.19
	Maximum silver	Short	269.51	8.11	268.35	8.39	464.56	4.88
		Closed	285.93	7.33	284.21	7.38	475.36	3.41
	Extreme Silver	Short	214.51	10.9	214.85	11.0	432.47	4.92
		Closed	248.40	6.67	246.11	7.36	449.23	4.45
1	Maximum clear	Short	104.89	8.04	105.48	5.00	210.23	9.21
		Closed	132.63	7.04	122.50	9.37	205.14	7.97
	Maximum silver	Short	110.72	11.0	98.80	5.17	222.65	8.70
		Closed	130.58	5.25	111.33	5.74	238.25	6.59
	Extreme Silver	Short	151.68	4.41	102.53	6.36	238.10	7.40
		Closed	179.09	5.36	139.24	5.00	264.66	9.74
7	Maximum clear	Short	104.89	8.04	80.12	5.69	170.23	9.21
		Closed	132.63	7.04	93.75	7.31	173.64	9.01
	Maximum silver	Short	81.32	11.3	67.10	4.72	165.15	9.08
		Closed	110.88	6.23	81.33	5.74	180.25	7.12
	Extreme Silver	Short	135.48	9.18	82.53	6.36	196.10	7.28
		Closed	169.59	5.52	119.24	5.00	224.66	9.74
14	Maximum clear	Short	95.64	8.05	74.88	5.82	150.63	12.6
		Closed	120.13	7.44	88.75	7.65	161.64	9.48
	Maximum silver	Short	73.67	11.4	62.10	5.02	143.65	9.54
		Closed	103.23	6.03	75.43	5.26	159.80	7.01
	Extreme Silver	Short	125.48	9.18	73.68	6.81	186.10	7.28
		Closed	149.59	5.52	108.74	4.72	214.66	9.74
21	Maximum clear	Short	92.64	7.91	71.33	7.71	140.13	12.6
		Closed	117.02	7.25	83.75	7.74	151.14	10.3
	Maximum silver	Short	70.57	11.4	57.40	5.24	133.65	9.54
		Closed	99.93	5.82	70.13	6.02	150.30	7.80
	Extreme Silver	Short	122.28	8.97	69.33	7.28	176.10	7.28
		Closed	145.39	6.14	103.29	4.65	204.66	9.74
28	Maximum clear	Short	90.59	7.98	68.13	7.82	134.48	12.7
		Closed	114.22	7.24	81.55	7.36	145.28	10.7
	Maximum silver	Short	68.03	11.2	54.50	5.52	126.75	8.17
		Closed	97.58	6.03	67.33	6.37	143.35	9.50
	Extreme Silver	Short	120.05	8.82	66.78	8.39	169.85	9.03
		Closed	141.64	7.15	99.94	4.69	198.95	11.4

Table 2: Descriptive data of the percentage of force decay of the elastomeric chains at different test periods and mechanisms

Days	Type		6-3 Mean	6-3 S.D.	6-5-3 Mean	6-5-3 S.D.	Chain loop Mean	Chain loop S.D.
0	Maximum clear	Short	0		0		0	
		Closed	0		0		0	
	Maximum silver	Short	0		0		0	
		Closed	0		0		0	
	Extreme Silver	Short	0		0		0	
		Closed	0		0		0	
1	Maximum clear	Short	61.89	2.40	68.89	1.25	56.33	1.89
		Closed	58.44	2.32	66.47	2.93	58.45	1.58
	Maximum silver	Short	58.88	4.29	63.16	2.08	52.07	1.95
		Closed	54.31	1.91	60.81	2.13	49.88	1.30
	Extreme Silver	Short	29.11	4.20	52.13	4.22	44.94	1.80
		Closed	27.86	2.81	43.39	2.22	41.09	2.10
7	Maximum clear	Short	69.21	2.61	76.36	1.74	64.64	1.89
		Closed	63.84	2.33	74.36	2.03	64.83	1.85
	Maximum silver	Short	69.81	4.29	74.97	1.97	64.44	2.04
		Closed	61.21	2.13	71.37	2.05	62.08	1.48
	Extreme Silver	Short	36.68	5.40	61.46	3.89	54.65	1.79
		Closed	31.69	2.60	51.53	2.11	49.99	2.10
14	Maximum clear	Short	71.92	2.59	77.90	1.83	68.71	2.63
		Closed	67.24	2.38	75.73	2.12	67.25	2.01
	Maximum silver	Short	72.65	4.30	76.83	2.12	69.07	2.14
		Closed	63.88	2.19	73.45	1.83	66.38	1.48
	Extreme Silver	Short	41.36	5.26	65.60	3.84	56.96	1.79
		Closed	39.75	2.49	55.80	1.82	52.22	2.10
21	Maximum clear	Short	72.81	2.52	78.94	2.42	70.89	2.62
		Closed	68.09	2.31	77.10	2.14	69.38	2.16
	Maximum silver	Short	73.80	4.28	78.58	2.20	71.22	2.14
		Closed	65.04	2.12	75.32	2.06	68.38	1.68
	Extreme Silver	Short	42.85	5.22	67.63	3.93	59.27	1.78
		Closed	41.44	2.68	58.02	1.73	54.44	2.10
28	Maximum clear	Short	73.41	2.53	79.88	2.44	72.07	2.64
		Closed	68.86	2.27	77.70	2.02	70.57	2.24
	Maximum silver	Short	74.75	4.18	79.66	2.29	72.71	1.76
		Closed	65.86	2.14	76.31	2.19	69.84	2.04
	Extreme Silver	Short	43.89	5.16	68.81	4.47	60.72	2.13
		Closed	42.95	3.17	59.38	1.78	55.72	2.45

Table 3: Differences in mean percent force decay at each time interval of elastomeric chains between mechanisms.

Days	Type		ANOVA test F- test	ANOVA test p-value	LSD test 6-3 / 6-5-3	LSD test 6-3 / Chain Loop	LSD test 6-5-3 / Chain loop
0	Maximum clear	Short					
		Closed					
	Maximum silver	Short					
		Closed					
	Extreme Silver	Short					
		Closed					
1	Maximum clear	Short	218.54	0.000	0.000	0.000	0.000
		Closed	78.24	0.000	0.000	0.99	0.000
	Maximum silver	Short	70.58	0.000	0.000	0.000	0.000
		Closed	183.32	0.000	0.000	0.000	0.000
	Extreme Silver	Short	214.74	0.000	0.000	0.000	0.000
		Closed	244.84	0.000	0.000	0.000	0.004
7	Maximum clear	Short	155.83	0.000	0.000	0.000	0.000
		Closed	156.12	0.000	0.000	0.14	0.000
	Maximum silver	Short	62.87	0.000	0.000	0.000	0.000
		Closed	173.48	0.000	0.000	0.16	0.000
	Extreme Silver	Short	206.99	0.000	0.000	0.000	0.000
		Closed	467.14	0.000	0.000	0.000	0.038
14	Maximum clear	Short	76.91	0.000	0.000	0.000	0.000
		Closed	101.44	0.000	0.000	0.99	0.000
	Maximum silver	Short	32.82	0.000	0.000	0.000	0.000
		Closed	143.31	0.000	0.000	0.000	0.000
	Extreme Silver	Short	198.82	0.000	0.000	0.000	0.000
		Closed	305.35	0.000	0.000	0.000	0.000
21	Maximum clear	Short	55.57	0.000	0.000	0.020	0.000
		Closed	97.54	0.000	0.000	0.069	0.000
	Maximum silver	Short	30.09	0.000	0.000	0.01	0.000
		Closed	143.25	0.000	0.000	0.000	0.000
	Extreme Silver	Short	208.02	0.000	0.000	0.000	0.000
		Closed	313.18	0.000	0.000	0.000	0.000
28	Maximum clear	Short	54.28	0.000	0.000	0.1	0.000
		Closed	92.66	0.000	0.000	0.016	0.000
	Maximum silver	Short	29.62	0.000	0.000	0.032	0.000
		Closed	123.37	0.000	0.000	0.000	0.000
	Extreme Silver	Short	189.57	0.000	0.000	0.000	0.000
		Closed	232.75	0.000	0.000	0.000	0.000

DISCUSSION

Effect of Different types

Examination of table (2) reveals that the extreme elastomeric chains has the least percent of force decay at the three mechanisms of canine retraction which is ranged between (27.86 % - 52.13 %) at the 1st day and remain having the smallest percent of force decay at the 28th day which ranged between (42.95%-68.81%) this finding proved the claim that the extreme elastomeric chains offer superior rebound qualities with less deformation over an extended period of time when compared to regular chains [13].

Effect of Different mechanisms

Examination of table (1) shows a range of initial forces (214.51–493.70 gm) in all three mechanisms. The (chain loop) mechanism always produced the highest initial force values (432.47–493.70 gm).The three mechanisms had varying mean percentage force decay values depending on the different types of elastomeric chains involved.

Examination of table 2 reveals that the range of percentage force decay in each mechanism over the first 24 h was as follows:

(6-5-3) mechanism: 43.39 -68.89 %.

(Chain loop) mechanism: 41.09 -58.45%.

(6-3) mechanism: 27.86- 61.89%.

After 28 days the range of force decay in each mechanism was as follow:

(6-5-3) mechanism: 59.38-79.88 %.

(Chain loop) mechanism: 55.72-72.71%.

(6-3) mechanism: 42.95-74.75%.

It is obvious from the above that the (6-5-3) mechanism has the highest percentage of force decay throughout the study, therefore it is not recommended to utilize this mechanism for canine retraction .The (chain loop) mechanism has the highest initial force values which are regarded as excessive physiological force values, therefore it is also not recommended to utilize this mechanism for canine retraction. The (6-3) mechanism has the smallest mean percentage force decay, therefore it is recommended to utilize this mechanism for canine retraction [12].

The present study suggests that in relation to the degradation behavior, the best brand of elastomeric chain is extreme elastomeric chain which consistently had a significantly lesser mean percentage force decay compared to regular type with respect to all three mechanisms.

For all the three types of elastomeric chains, mechanism three (6-3) had the smallest mean percentage force decay. This finding suggests that it may be most efficient to retract a canine utilizing elastomeric chain directly from the molar hook to the canine bracket. The chain loop mechanism may not be indicated for space closure in vivo due to the excessive physiological force values involved with the mechanism.

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