Effect of Different Artificial Saliva on the Mechanical Properties of Orthodontic Elastomers Ligatures

DANA CRISTINA BRATU[1]*, SILVIA-IZABELLA POP[2]*, RALUCA BALAN[1], MIRCEA DUDESCU[5] , HORATIU POMPILIU PETRESCU[3], GEORGE POPA[4]

[1]University of Medicine and Pharmacy "Victor Babes", Faculty of Dentistry, Department of Paedodontics and Orthodontics, 9 Revolution Str., 300070, Timisoara, Romania

[2]Private practice, 1 Caraiman Str., 540389, Târgu Mureş, Romania

[3]University of Medicine and Pharmacy Victor Babes, Department of Orthopaedics, 9 Revolution Str., 300070, Timisoara, Romania

[4] University of Medicine and Pharmacy "Victor Babes, Department of Endodontics, Faculty of Dentistry, 9 Revolution Str, 300070, Timisoara, Romania

[5]Technical University of Cluj-Napoca, Department of Mechanical Engineering, 28 Memorandumului Str., 400114, Cluj-Napoca, Romania

It was evaluated, in vitro, the effect of different artificial saliva on the mechanical properties of elastomeric ligatures. A total number of 160 elastomeric ligatures were divided in four groups (n=40 in each group). Three groups were exposed to three types of artificial saliva, (unmodified artificial saliva, with coca cola and with topical fluoride agent), for a period of 28 days. The fourth group (control group) remained unexposed. Tensile load at failure was determined by stretching the ligatures using an Instron Universal Testing Machine, until they fractured. The obtained data was statistically analyzed at a level of significance ($p < 0.05$). The two-way ANOVA showed significant statistical differences within groups ($p < 0.001$) and between time intervals ($p < 0.005$). There were a statistical significant interaction between groups and time on tensile load at failure ($p < 0.005$). Artificial saliva, Coke and Topical Fluoride seem to cause an increase in force decay of elastomeric ligatures, with a decrease in tensile load at failure over time.

Keywords: elastomeric, orthodontics, tensile load.

Elastomeric ligatures are commonly used for ligating orthodontic archwires to brackets. The ease in application and cost efficiency make them more popularly used than other forms of ligation (e.g., wire ligatures, selfligating brackets) [1].Generally, elastomers are polyurethanes, polymer products made by a polymerization process, possessing a –(NH)–(C=O)–O– unit [2].

A number of studies have been conducted to evaluate their mechanical properties, in various environments and different testing conditions [3-15]. Factors such as, temperature changes, *p*H variations, oral fluoride rinses, salivary enzymes, and masticatory forces have all been associated with the deformation, force degradation, and relaxation behaviour of these elastomers [4,5,8,10]. For orthodontic ligatures, maintenance of force delivery is needed to sustain full engagement of archwires in the bracket slot and in effect, it also has a great influence on the teeth movement [16]. Unfortunately, these elastomeric ligatures frequently fail during clinical use. In attempts to mimic various oral environments, some studies have investigated the effects of simulated saliva environments, *p*H, and thermocycling on force degradation [3,4,8]. Various artificial saliva have been proposed, with the simplest formulation being 0.09% aqueous sodium chloride, commonly used in simulated intraoral environment studies [12]. Generally, the data demonstrated significant relaxation of force once the elastics were exposed to experimental conditions, but a discrepancy also, has been documented in the literature through different protocols adopted. While the intermaxillary elastics are repeatedly changed by the patients, the elastomeric chains and ligatures remain in place for a variable period of time, from a few weeks to a few months. During this period of wear, these patients consume foods and physically stress the ligatures, exposing them to thermal, chemical, and mechanical challenges, most of which have not been fully investigated with regard to their effects on the degradation of orthodontic polymers [12,14]. Coke® was used as a test substance as it is a popular drink with younger patients.

Compromised oral hygiene, a frequent complication with orthodontic treatment, can lead to enamel demineralization and decay [17]. To address this potential treatment complication, orthodontists commonly prescribe a daily topical fluoride. The effect of Fluor on the elastic ligatures was evaluated in a few studies [5,17].

The aim of the present study was to investigate the influence of three types of artificial saliva (unmodified artificial saliva, with coca cola and with topical fluoride agent) on the failure load of the elastic ligature.

Experimental part

Materials and methods

A total number of 160 elastomeric ligatures (GAC, Gac Company™) were divided in four groups (n=40 in each group). Three groups were exposed to three types of artificial saliva:

Group 1: artificial saliva, with the following composition:

- sodium chloride ($NaCl$) = 8 g;
- potassium chloride (KCl) = 8 g;
- disodium hydrogen phosphate 1-hydrate ($Na_2H, PO_4 . H_2O$) = 13.8 g;
- sodium sulphide ($Na_2S. 9H_2O$) = 0.1g;
- urea = 20 g;
- calcium chloride ($CaCl_2 – H_2O$) = 15.9 g;
- distilled water = 20 L;
- *p*H = 7.

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* email: danacristinabratu@yahoo.com; kecsetisilvia@yahoo.com

Group 2: artificial saliva with 50% coca cola (Coca Cola) with the following composition: phosphoric acid, sugar, carbon dioxide, flavor, *p*H = 2.6.

Group 3: artificial saliva with 50% topical fluoride agent (Home care fluoride gel, Dental Technologies, Illinois, USA) with the following composition: staneous fluoride 0.4%, ascorbic acid, carbomer, citric acid, flavor, glycerine.

The test groups were independently submerged in solution, incubated at 37°C and monitored daily with a digital thermometer and thermostat (Falc WB M5, Falc Instruments Italy) (fig. 1). In addition, ligatures unexposed to solution were tested. The fourth group (control group) remained unexposed and all control ligatures were stored dry at room temperature (22 ± 2°C), unexposed to light. Force measurements were performed on 10 ligatures at four different time intervals (7, 14, 21, and 28 days), for every group and time interval, respectively.

Fig. 1. Instron Universal Testing Machine type 3366, 10 kN

Mechanical testing was performed by placing a specimen in a custom made jig (made of 0.9 mm Stainless steel) comprised of two metal pins attached respectively to the fixed and movable crossheads of a universal testing machine (Instron Universal Testing Machine type 3366, 10 kN – Instron Corporation, Canton, MA). The measured values were recorded for each specimen by the testing machine software Instron Bluehill 2. The collected data can be exported in spreadsheet file format (Microsoft Excel).

The testing machine is represented in figure 2. Each ligature was loaded in tension at a crosshead speed of 100 mm/min until fracture occurred (fig. 3). Maximum tensile load was recorded in Newtons. The tensile load at failure was used as a correspondent to the clinical situation of ligature failure during tie-in.

Fig. 2. Falc WB M5 thermostat used for the study.

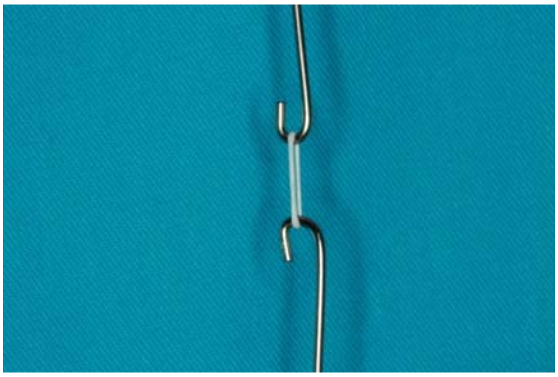

Fig. 3. Customized jig used to test the tensile load at failure of the ligatures

The collected data were statistically analyzed using the program IBM SPSS Statistics 21.0 (SPSS Inc., Chicago, IL). In order to check the assumptions of normality and outliers, studentized residuals were calculated and afterwards, the data were tested with Shapiro-Wilk's normality test of residuals. A two-way repeated measures analysis of variance (within-within-subjects ANOVA) was used to determine significant differences between groups and whether a statistically significant interaction term between groups and exposure time was expected. Post hoc pairwise comparison tests (Bonferroni's correction applied for confidence interval adjustment) were performed subsequently, when ANOVA indicated a statistical difference in the model.

A level of confidence of 95% was used for all statistical calculations ($p < 0.05$).

Results and discussions

The normality Shapiro-Wilk's test showed that the collected data were normally distributed (the residuals were normally distributed, $p > 0.142$).

Table 1 shows the results for the tensile load at failure, using descriptive statistical analyses, including means and standard deviations, performed for each individual group, at different time intervals. The control group showed no significant differences at different time intervals.

The two-way ANOVA showed significant statistical differences within groups ($p < 0.001$) and between time intervals ($p < 0.005$). There was a statistically significant interaction between groups and time intervals (Greenhouse-Geisser correction, $p < 0.005$), as shown in table 2. Further post- hoc tests (pairwise comparisons) correlated with the estimated marginal means of group and time (fig. 4) produced the following results:

Table 1

DESCRIPTIVE ANALYSES, INCLUDING MEAN VALUES (NEWTONS) AND STANDARD DEVIATION (SD) PERFORMED FOR EACH INDIVIDUAL GROUP (n=10)

	Group			
	1	**2**	**3**	**4**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
7 days	20.41 (1.61)	20.19 (1.65)	19.61 (1.53)	23.65 (1.22)
14 days	19.76 (1.52)	17.30 (1.63)	19.98 (2.01)	23.53 (1.45)
21 days	18.75 (1.32)	16.98 (1.21)	16.76 (1.60)	23.43 (1.67)
28 days	18.67 (1.84)	15.81 (1.89)	16.97 (1.26)	23.55 (1.19)

Table 2
ANOVA TEST SHOWING SIGNIFICANT DIFFERENCES WITHIN GROUPS ($p < 0.001$) AND TIME INTERVALS ($p < 0.005$)

Two-way ANOVA (Tests of Within-Subjects Effects)							
Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group	Sphericity Assumed	850.022	3	283.341	86.778	.000	.906
	Greenhouse-Geisser	850.022	1.973	430.741	86.778	.000	.906
	Huynh-Feldt	850.022	2.524	336.798	86.778	.000	.906
	Lower-bound	850.022	1.000	850.022	86.778	.000	.906
Time	Sphericity Assumed	128.663	3	42.888	17.134	.000	.656
	Greenhouse-Geisser	128.663	1.687	76.252	17.134	.000	.656
	Huynh-Feldt	128.663	2.034	63.258	17.134	.000	.656
	Lower-bound	128.663	1.000	128.663	17.134	.003	.656
Group * Time	Sphericity Assumed	83.216	9	9.246	5.617	.000	.384
	Greenhouse-Geisser	83.216	3.647	22.819	5.617	.002	.384
	Huynh-Feldt	83.216	6.438	12.925	5.617	.000	.384
	Lower-bound	83.216	1.000	83.216	5.617	.042	.384

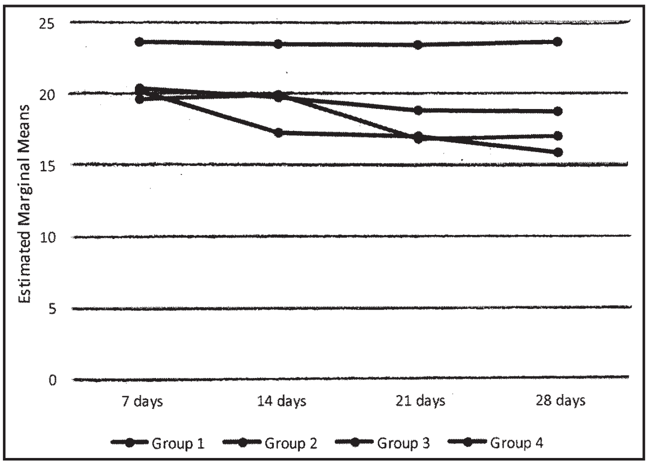

Fig. 4. Estimated Marginal Means of Group and Time

- statistically significant differences were found between the mechanical properties of the testing groups and the control group, during the testing period ($p < 0.05$).

- tensile load at fracture was not statistically significant different in group 1 (M = 20.41, SE = 0.512 N) compared to group 2 (M = 20.190, SE = 0.524 N) at the 7 days time point ($p = 0.147$).

- regarding the second time interval (14 days): significant differences were found between group 1 and 2 ($p < 0.005$), between group 2 and 3 ($p < 0.005$), but not between group 1 and 3 ($p = 1.00$).

- statistically significant differences were found in the third time interval (21 days), both between testing groups and control group ($p < 0.001$) and between group 1 and 2 ($p < 0.01$).

- testing results on the 28th day are statistically significant different between group 1 and 2 ($p < 0.05$).

- within the same group, significant differences were obtained: in the group 1 and 2 for the 7-14 days interval and in the group 2 for the 14-21 days interval.

Polyurethanes are not inert materials and instead are subject to water absorption and degradation with prolonged contact with enzymes, water, and other organic and inorganic compounds [14,18]. This study was undertaken to see what effect, prolonged, continuous exposure of polyurethane elastomeric ligatures to Coca Cola, fluoride gel and artificial saliva have upon their strength.

The decrease in tensile load at failure after exposure to different solutions observed in this study parallels some of the results [5]. The failure load seemed to be affected by each of the three solutions.

A controversial result was reported by Nattrass et al [13]. The study evaluated the influence of three common environmental factors on the force degradation of elastomeric chains in an aqueous medium (Coca-Cola, a medium rich in additives), with temperatures controlled at 10, 22, and 37°C. All media influenced the elastomeric chains, although the high temperature may have influenced the results. In the present study, a constant temperature of 37°C was maintained, which corresponds to the body temperature.

The *in vivo* behaviour of the modules may be different, due to such variables as masticatory forces, wide temperature modifications and oral hygiene behaviour. Also the specific bioflora and its bioproducts may contribute to the alteration of these polymeric materials [18].

Huget et al [19] exposed orthodontic elastomers to distilled water for 1, 7, 14, 42, and 70 days and examined the storage solutions for leached organic substances. Their study showed that leached organic substances were detected only after 14 days of storage, which means that a time-dependent degradation occurs in orthodontic polyurethanes. They stated that water absorption first leads to plasticization followed by chemical degradation of the elastomers.

Time of exposure was a significant factor in this study. The strength values of the elastomeric ligatures gradually decreased with every interval. Therefore, more studies are needed in order to evaluate the *in vitro* degradation of the ligatures. In conclusion, the present findings might be useful to anticipate the clinical behavior of the modules.

Conclusions

There were statistically significant differences in the failure loads of the elastomeric ligatures, on each testing interval and group.

Artificial saliva, Coke and Topical Fluoride seem to cause an increase in force decay of elastomeric ligatures.

Compared to unexposed specimens, tensile load to failure of elastomeric ligatures decreased when exposed to solutions for one week or more.

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