Initial Tensile and Residual Forces of Pigmented Elastomeric Ligatures from Various Brands

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Abstract. This study aimed to investigate the initial tensile and residual forces of pigmented elastomeric ligatures (clear, pink, and metallic) from three commercial brands – Brand 1 (USA), Brand 2 (USA), and Brand 3 (China). Twelve elastomeric ligatures of each brand and color were evaluated for initial tensile and residual forces after stretching for 28 days at 37°C by a Universal Testing Machine. The results showed that the highest initial tensile force was 14.78 N, 20.71 N, and 15.1 N for the metallic color of Brand-1, pink color of Brand-2, and metallic color of Brand-3, respectively. There were significant (p<0.05) differences in the initial tensile force of each brand, except clear and metallic color of Brand-1 & 3 and pink color of Brand-2 & 3. Similarly, among the pigmented ligatures from each brand, significant (p<0.05) differences were observed in the initial tensile force, except metallic color of Brand-1 & 3. Brand-3 had the highest residual force after 28 days, whereas the loss of force was 80-90% in Brand-1 & 2 and 20-30% in Brand-3. There were also significant (p<0.05) differences in the residual forces in each color and brand, except metallic color of Brand-1. In conclusion, there were significant differences in the initial tensile and residual forces among the three pigmented elastomeric ligatures of the three commercial brands.

1. Introduction

Since their first introduction in orthodontics more than three decades ago, elastomeric modules have gained universal acceptance by the profession. They are made up of polyurethane, which is a generic term associated with elastic polymers with a urethane linkage [1] and are used in the form of ligatures and chains or modules [2] to ligate archwires to orthodontic bracket. They have key benefits such as low cost, easy application, reduced chair time, patient comfort, and satisfaction.

Securing archwires with a single elastomeric module produces forces of 50-150 g [3]. The force exerted by an elastomeric ligature depends on the initial force and force rate. These elastomers have two important properties- tensile strength (TS) and extension to TS. The TS can be defined as the maximum force a material can bear before breakage and rupture. An extension to TS is measured as the extension at which maximal stress occurs [4].

Over the years, there has been an increased patient demand for esthetically pleasing appearance during treatment with fixed appliances, promoting the need for esthetic accessories. To meet these demands, many companies have produced elastomeric ligatures in different colors. There have been some studies that have reported differences in mechanical characteristics between clear and pigmented elastomeric chains, but few studies have focused on elastomeric ligatures [5,6]. Therefore, the purpose
of this in vitro study was to investigate elastomeric ligatures from three commercial brands available in Thai market with 3 different colors (clear, pink, and metallic) for their initial tensile force and force loss after stretching for 28 days.

2. Materials and Methods

Clear, pink, and metallic pigmented orthodontic elastomeric ligatures from 3 commercial brands, Brand-1 (C-1, Dynaflex USA), Brand-2 (C-2, Ormco USA) and Brand-3(C-3, W&H China) were used in this study. All samples were categorized into 9 groups according to the brands and colors (Table 1). The tensile property was tested according to ISO 21606:2007, which measured the initial tensile force and, then, the residual force after stretching the ligatures for 28 days at 37°C. For each test, twelve modules of each brand and color were randomly selected.

2.1 Initial tensile force
The module was stretched using two half rods (radius 0.5 mm.) on a Universal Testing Machine (Instron 5566, Instron Corp., Buckinghamshire, UK, England) and extended at a cross-head speed of 100 mm/minute to 0.155 inches (diagonal length of upper central incisor bracket) and held for 5 seconds. The force exerted was determined in Newtons at 30±2 seconds after reaching the latter extension, following which the results of the initial extension force of each brand were compared. This test was performed at 23±2°C at a relative humidity of 50±10%.

2.2 Residual force
The module was stretched using two stainless pin at 0.155 inches distance (diagonal length of upper central incisor bracket) on a supporting plate. All samples are stored in water (ISO 3696:1987, Grade 3) at 37±2°C for 28 days. The support plate was then removed maintaining the extended condition of the samples and immediately placed in water (ISO 3696:1987, Grade 3) at 23±2°C for 30±2 mins. The samples on the support plate was removed from water and transferred to the Universal Testing Machine. The residual force was determined in Newtons at 0.155 inches (diagonal length of upper central incisor bracket) exerted at 23±2°C. Residual forces were calculated as the percentage of the initial extension force using the following formula-

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\text{Percentage of residual force} = \frac{\text{residual force} \times 100}{\text{initial extension force}}
\]

3. Statistical analysis
Two-way ANOVA was used to test the effect of brand and color on initial extension force. Multiple linear regression was employed to test the effect of brand and color on percentage of residual force. Multiple comparison by Bonferroni’s test was used to compare the measurements among the groups. The level of statistical difference was accepted at p-value<0.05.

4. Results
From the results for the tensile force (Table 1), the metallic pigmented ligatures of C1 and C3 had the highest initial tensile force followed by pink and clear colors, respectively. However, the pink color of C2 had the highest initial tensile force followed by metallic and clear colors, respectively. The percentage of force loss after stretching for 28 days was 78-84% for C-1, 79-89% for C-2, and 19-27% for C-3. There were significant (p<0.05) differences in the initial tensile force among the brands in each color, except clear and metallic colors of C1-C2 and pink color of C2-C3 (Table 2). Considering the pigmented ligatures of each brand (Table 3), significant (p<0.05) differences were noted in the initial tensile force among the pigmented ligatures of each brand, except pink-metallic color of C1 and C3. There were also significant (p<0.05) differences in the residual tensile force among the brands for each color (Table 4). For the pigmented ligatures of each brand (Table 5), there were significant
(p<0.05) differences in the residual tensile force among the pigmented ligatures of each brand, except pink and metallic color of C1.

Table 1. Means of initial extension and residual forces at 28 days

| Brands | N group | color       | Initial Force | Residual force | % Force Loss |
|--------|---------|-------------|---------------|----------------|--------------|
|        |         |             | X  | S.D | X  | S.D |              |
| C1     | 12      | Clear       | 11.05 | 0.76 | 2.11 | 0.13 | 80.9          |
|        |         | Pink        | 11.22 | 0.43 | 2.38 | 0.25 | 78.79         |
|        |         | Metallic    | 14.78 | 3.47 | 2.32 | 0.19 | 84.3          |
| C2     | 12      | Clear       | 10.83 | 0.55 | 2.27 | 0.03 | 79.04         |
|        |         | Pink        | 15.10 | 0.85 | 1.54 | 0.04 | 89.8          |
|        |         | Metallic    | 13.63 | 0.29 | 2.14 | 0.05 | 84.3          |
| C3     | 12      | Clear       | 8.38  | 0.82 | 6.74 | 0.59 | 19.57         |
|        |         | Pink        | 19.61 | 1.50 | 14.26 | 1.16 | 27.28         |
|        |         | Metallic    | 20.71 | 1.71 | 15.96 | 1.31 | 22.94         |

Table 2. Differences in initial tensile force based on brands and colors

| Initial Tensile Force | Color       | Clear | Pink | Metallic |
|-----------------------|-------------|-------|------|----------|
| Brand                 | C1          | C2    | C3   |          |
| C1                    | -           | NS    | S    | S        |
| C2                    | NS          | -     | S    | S        |
| C3                    | S           | S     | -    | S        |

Table 3. Differences in initial tensile force based on brands and colors

| Initial Tensile Force | Color       | Clear | Pink | Metallic |
|-----------------------|-------------|-------|------|----------|
| Brand                 | C1          | C2    | C3   |          |
| Clear                 | -           | S     | S    |          |
| Pink                  | S           | -     | NS   | S        |
| Metallic              | S           | NS    | -    | S        |

Table 4. Differences in residual tensile force on based on brands and colors

| Residual Tensile Force | Color       | Clear | Pink | Metallic |
|------------------------|-------------|-------|------|----------|
| Brand                  | C1          | C2    | C3   |          |
| C1                     | -           | S     | S    | -        |
| C2                     | S           | -     | S    | S        |
| C3                     | S           | S     | -    | S        |

Table 5. Differences in residual tensile force based on brands and colors

| Residual Tensile Force | Color       | Clear | Pink | Metallic |
|------------------------|-------------|-------|------|----------|
| Brand                  | C1          | C2    | C3   |          |
| Clear                  | -           | S     | S    | -        |
| Pink                   | S           | -     | NS   | S        |
| Metallic               | S           | NS    | -    | S        |
5. Discussion
This study compared 3 brands of polyurethane-based elastomeric modules which were made in two
different countries with a wide variety of mechanical properties [7]. Overall, the ligature quality and
composition is a result of a combination of technology, technique refinement, and quality of the raw
materials used during manufacturing [1,8] but this information are generally withheld by the
manufacturers [7,9]. When exposed to the oral environment for a lengthy period of time, these
ligatures absorb water and saliva, which disrupts the internal connections in the polymer network,
thereby, promoting permanent deformation [9].

The testing methods employed in this study followed ISO21606:2007 that was designed to simulate
the clinical situation of extended elastomeric ligature by using a calibrated Universal Testing Machine.
Although there have been some studies on tensile strength (TS) of elastomeric ligature at breaking
point [4,10,11], it may not be applied in clinical practice because the elastomeric ligatures are only
extended around the diameter of the bracket to engage archwire with bracket wings. Indirect
measurement of the structure and mechanical properties of these polymers provides insight into the
loss of force. The results of this study showed that all elastomeric ligatures decreased in tensile force
after 28 days. Percentage of force loss in 28 days were 78-84% for C1, 79-89% for C2, and 19-27%
for C3. These results were in confirmation with previous studies that presented similar pattern of force
deay and 50-60% of force loss during the first 24-hour interval [1,12,13]. C1 and C2 were nearly
consistent with these reported values and can be considered as clinically acceptable when compared to
commercially available products. However, C3 had a higher tensile force even after 28 days.

The results also found that there were significant differences among each color of each brand. The
addition of pigments to elastomeric ligature by manufactures to increase patient acceptance might
have affected their mechanical properties, esp. in terms of initial force and residual force after 28 days.
In a previous study, Lam et al. found that the addition of coloring materials to ligatures effected tensile
strength. The filler materials added for tinting of the elastomeric chains can affect their polymer
network and, hence, their properties, as shown by Anthony and Paulose [14], who noted less force
delivery and greater force decay in pigmented elastomeric chains as compared to non-pigmented ones
and that these values differed according to the color and the manufacturer. Moreover, Renick and
colleagues [6] observed significant differences in the glass transition temperatures of gray and purple
pigmented elastomeric chains. Taloumis et al [1] found a negative correlation between the inner
diameter and force. In addition, Boonyarangkul [15] noted a positive correlation between cross-section
thickness and initial extension force. However, this paper did not measure the size of elastomeric
ligatures.

The findings from this study provided data of a simulated clinical condition, that may be different
from the forces provided by elastomeric ligatures in the oral cavity. In vivo observations of force
delivery from modules may reveal lower amount of force due to pH and temperature variations in the
oral environment, along with the accumulation of plaque and formation of microbial colonies on
elastomeric modules. Ash and Nikolai [13] found that force degradation is more rapid in water and
oral environment than in air. In addition, the decay in the oral environment become statistically greater
than in water after 10 days.

Assessments of the physical properties of elastomeric ligatures have reported significant changes in
the structure and composition of these materials after exposure to the oral environment [1,16]. After
exposure to the oral environment for 3 weeks and subsequent analysis by optical microscopy and
spectroscopy, the elastomeric ligatures exhibited precipitates of calcium phosphate on the surface.
Significant changes were found in the structure and composition of their surface following exposure to
the oral environment, indicative of the severity of changes that can occur in the properties of these
materials [16]. In this study, there were differences in the tensile forces among the brands and colors
which may have resulted due to variations among the manufacturers in the processing technique,
composition, and size of elastomeric ligatures.
6. Conclusion
Significant differences were observed in the initial tensile and residual forces among the three pigmented elastomeric ligatures tested in this study from three different manufacturers.

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