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Tensile Strength and Force Degradation for Orthodontic Elastics Used In A Presurgical Orthopedic Appliance In Infants With Bilateral Cleft Lip And Palate

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ABSTRACT

INTRODUCTION: Cleft lip and palate (CLP) is considered a debilitating condition because of its effect on hearing, speech and psychology of the children with CLP. The bilateral cleft lip and palate (BCLP) deformity appears with a protruded and rotated premaxilla. Several presurgical orthopedic appliances are required to achieve retraction of the premaxilla using orthodontic elastics. The selection of the size of the elastic and the period of replacement of the elastics should be known.

OBJECTIVES: The study aims to evaluate the tensile strength and force degradation of orthodontic elastics used in presurgical orthopedic appliances in infants with BCLP.

MATERIALS AND METHODS: Ten new orthodontic elastic (ORMCO) elastics of each of the sizes ¼, 5/16 and 3/8 inch were used. Ten used elastics of each the three sizes mentioned previously were also tested. The used elastics were obtained from infants with presurgical orthopedic appliance who used the elastics for three days. Tensile tests were performed on both new and used elastics using the Mcmesin tensile testing machine and the elastics were stretched to 50 mm and the forces were recorded throughout the tests.

RESULTS: Data was collected and statistically analyzed. The results showed that the forces obtained when the elastics were stretched to three times their lumen diameter were 5-7 % less than that stated by the manufacturer which is not a significant percentage. The force degradation of the elastics after three days of use was 38.5 to 42%.

CONCLUSIONS: The size of the orthodontic elastics used in presurgical orthopedic appliances for infants with BCLP can be selected based on stretching the elastic three times its lumen diameter. The elastics can be used for 3 days to maintain a constant force to achieve retraction of the premaxilla then changed to new ones.

KEYWORDS: Cleft Lip and Palate, orthodontic elastics, tensile strength, force degradation, presurgical orthopedic appliances

INTRODUCTION

Cleft lip and palate (CLP) is a common deformity in the craniofacial region. It represents a public health problem due to possible associated morbidity and extensive commitment required for intervention. It is a debilitating condition that may affect feeding, hearing, speech and may have a psychological impact by time [(1)].

Bilateral cleft lip and palate (BCLP) presents with a protruded premaxilla which is detached from the maxillary segments resulting in three separate components. The abnormal muscle forces result in pulling of the lateral palatal segments increasing the cleft gap [(2)].

Management of CLP is an extensive process that starts in infancy and continues to adulthood. These patients require many surgical procedures. Timing for the surgery to repair the cleft lip extends from the neonatal period to 5 to 6 months of age [(3,4)]. However, timing for cleft palate repair is delayed to around 12 months of age before speech development [(5)].

Despite the various improvements in the surgical techniques, specific orthopedic modifications before the primary surgery are needed in patients with CLP to improve the prognosis and to be able to achieve lip repair with reduced tension and scar formation [(6)].

These modifications are achieved using presurgical orthopedic appliances. There are many designs of presurgical appliances that achieve retraction of the premaxilla. Some designs consist of two pieces, a piece covering the premaxilla, and a second part covering the maxillary segments. Retraction of the premaxilla can be achieved by screws that require daily activation [(7)], retracting spring [(8)], orthodontic elastomeric chains and orthodontic elastics.

Elastics are made from natural rubber and can recover and return to their original form after deformation [(9)]. Natural rubber is a kind of elastomer that forms a three-dimensional reticulate structure by cross-links [(10)].

Orthodontic elastics possess elastic properties that depend on twisted long molecular chains that have an irregular arrangement and are linked together by covalent bonds between different atoms such as Sulphur with two carbon atoms. When the Latex elastic exceeds its stress limit, its lack of homogeneity on the surface causes fatigue to occur at its weak points. Dynamic fatigue occurs simultaneously by friction between the molecular chains [(11)].

The physical and chemical properties of the latex cause orthodontic elastics to undergo fatigue and force relaxation. This results in force degradation which is aggravated under adverse environmental conditions, such as in the oral cavity [10].

There are numerous factors present in the oral cavity, including variations in pH, temperature, enzymatic and microbial action. These factors in addition to intermaxillary elastic elongation in these media, are the cause of force decay of the orthodontic elastics [12,13].

Force levels on elastic packs, stated by the manufacturer, are obtained when stretching the elastic three times the size of the lumen. However, studies found that the force levels on elastic packs were closer stretching the elastic twice its lumen dimaeter [10,14]. Force degradation occurs due to fatigue of the elastics by loading and stretching, resulting in a change in their chemical and physical properties. Studies have shown large amounts of force degradation up to 30% are exhibited by the elastics, which were greatest within the first hour of use [12,15].

Loriato et al, have indicated that the latex elastics need replacement every three days because there was no difference in force release between 24 and 72 hours. The elastics should be activated for a more extended period to provide a constant force to achieve the desired outcome[17].

Qodcieh et al, found that 50% of the force degradation occurred in the first 4 to 5 hours then the rate of degradation declined over the 48 hours. They concluded that the elastics can be used for 48 hours but can be changed daily for oral hygiene purposes [18]. In general, most of the studies showed that the most significant force loss occurred within the first hour, then the force decay decreased until 24 hours [18,19].

Notaroberto, Goldner, Mendes, & Quintão (2018) evaluated the force decay over time of latex and non-latex elastics. A tensile testing machine was used and the elastics were stretched to 25 mm. the highest level of force decay occurred during the first hour after stretching then the decay became slower by time [20].

Despite the various studies in the literature, there is a lack of studies evaluating the tensile strength and force decay of orthodontic elastics in infants with CLP. The aim of this study is to evaluate the tensile strength and force degradation of orthodontic elastics used in presurgical orthopedic appliances in infants with BCLP to be used as a guide for selection of the proper size

of the elastic and determine the period of replacement of the elastics to maintain the force required for retraction of the premaxilla.

MATERIALS AND METHODS

Samples of 10 new orthodontic elastics (ORMCO Z-pack elastics, Mexico) for each of the sizes 1/4, 5/16, 3/8 inch with a force of 4.5 oz. were used in this study. The tests were performed using the Mecmesin (Multi Test 5-XT) machine with a test speed of 15 mm/min in the Central Materials Lab in Faculty of Engineering, Alexandria University.

The elastics were mounted between stainless steel hooks which were designed to accommodate the elastics and allow for the tensile tests to be performed **(Fig. 1)**. The elastics were stretched until a distance of 50 mm and the forces were recorded.

(a) (b)

Fig. (1): Tensile testing of the orthodontic elastics.

(a) Two designed stainless steel hooks for mounting the orthodontic elastics.

(b) The stainless steel hooks with the orthodontics elastics clamped in the machine.

The tests were also performed on 10 orthodontic elastics of the same sizes which were used by infants using the presurgical orthopedic appliance for 3 days to determine the percentage loss of the forces of the orthodontic elastics after three days **(Fig. 2)**.

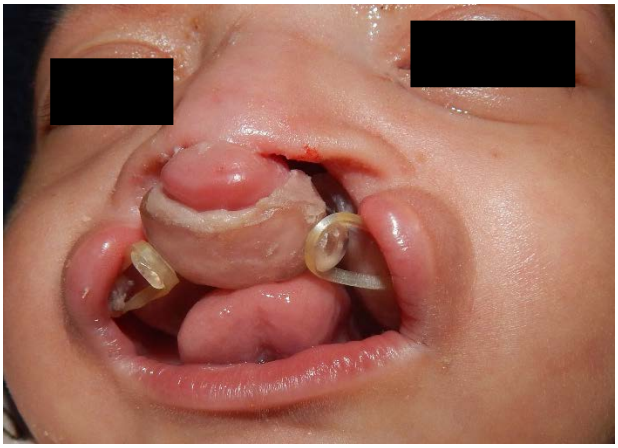

Fig. (2): Presurgical orthopedic appliance with orthodontic elastics in place.

The percentage loss of force was calculated as follows:

$$\textbf{\textit{Percentage loss}}\ (\%) = \frac{Force\ (New\ elastic) - Force\ (Used\ elastic)}{F\ orce\ (New\ elastic)}\ x\ 100$$

RESULTS

The elastic response of 1/4 inch orthodontic elastics is shown in Figure 3. The curves shown below are the average results of ten new and used elastics.

The results show that a force of 1.2 N was applied when the new elastic was stretched 3 times of its diameter. On the other hand, a force of 0.71 N was applied to obtain 3 times of the diameter of the used elastic (after 3 days in the infant's oral environment). This was less than the force applied on the new one by 40.8 %.

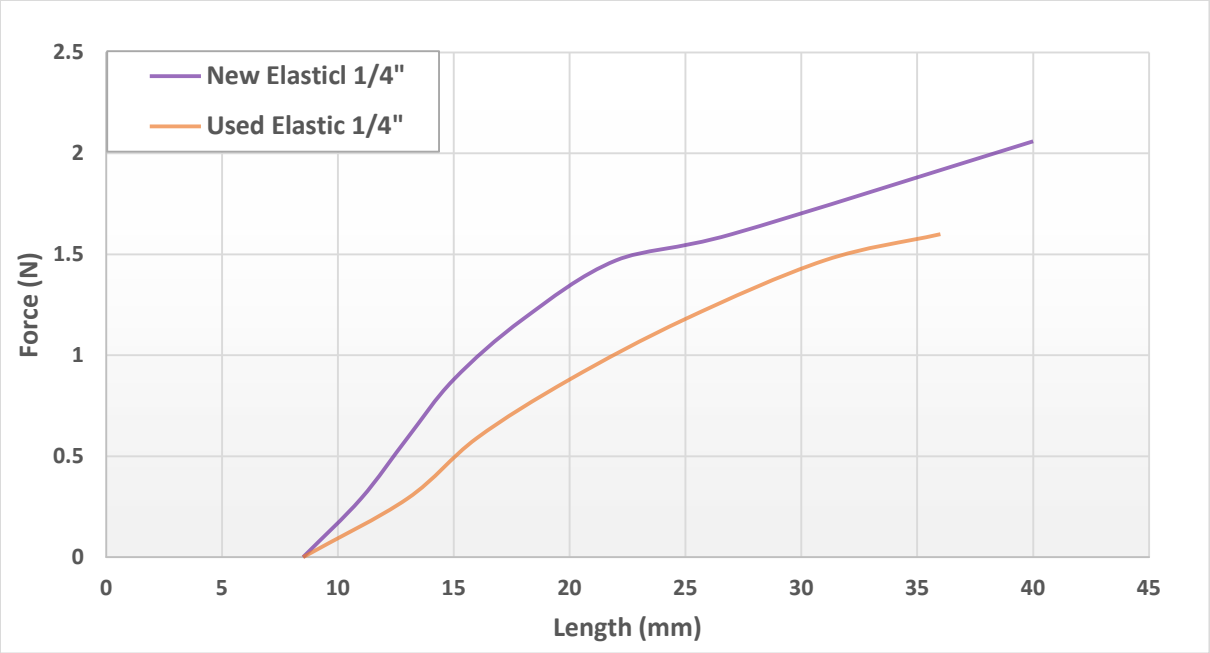

Fig. (3): Curves showing the force applied in relation to the length of the 1/4 inch Ormco orthodontic elastics (new and used).

Figure 4 shows the elastic response of 5/16 inch orthodontic elastics. The curves shown below are the average results of ten new and used elastics.

The results show that a force of 1.18 N was applied when the new elastic was stretched 3 times its diameter. On the other hand, a force of 0.68 N was applied to obtain 3 times of the diameter of the used elastic (after 3 days in the infant's oral environment). This was less than the force applied on the new one by 42.3 %.

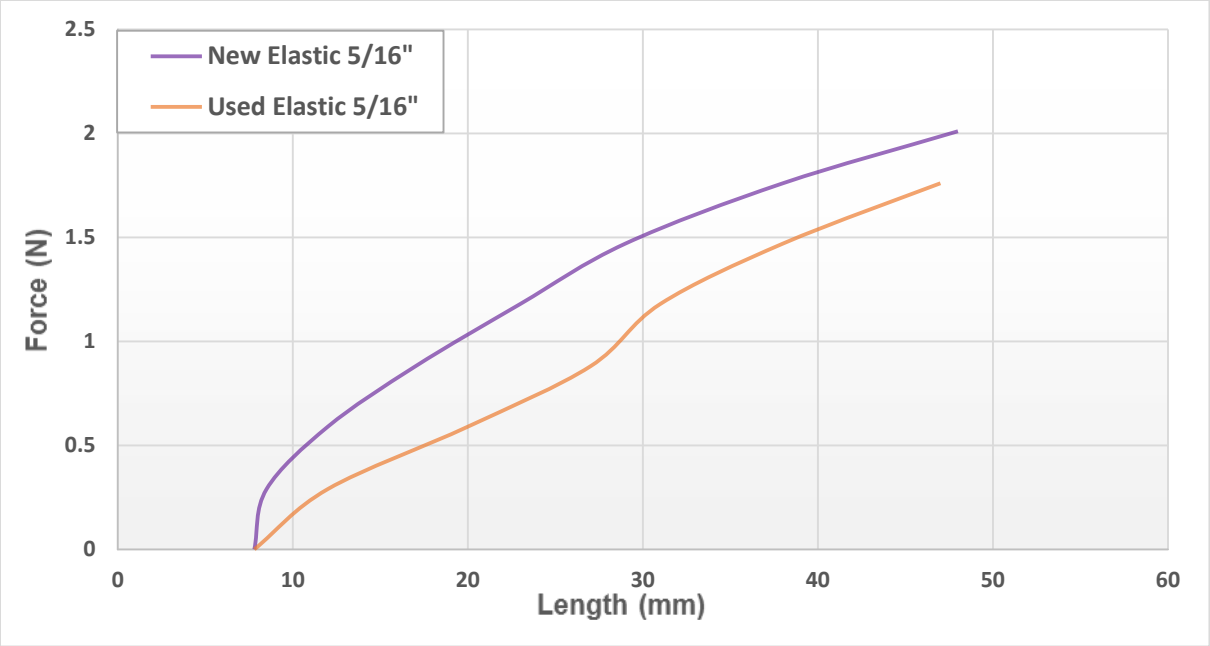

Figure (4): Curves showing the force applied in relation to the length of the 5/16 inch Ormco orthodontic elastics (new and used).

Figure 5 shows the elastic response of 3/8 inch orthodontic elastics. The curves shown below are the average results of ten new and used elastics.

The results show that a force of 1.22 N was applied when the new elastic was stretched 3 times of its diameter. On the other hand, a force of 0.75 N was applied to obtain 3 times of the diameter of the used elastic (after 3 days in the infant's oral environment). This was less than the force applied on the new one by 38.5%.

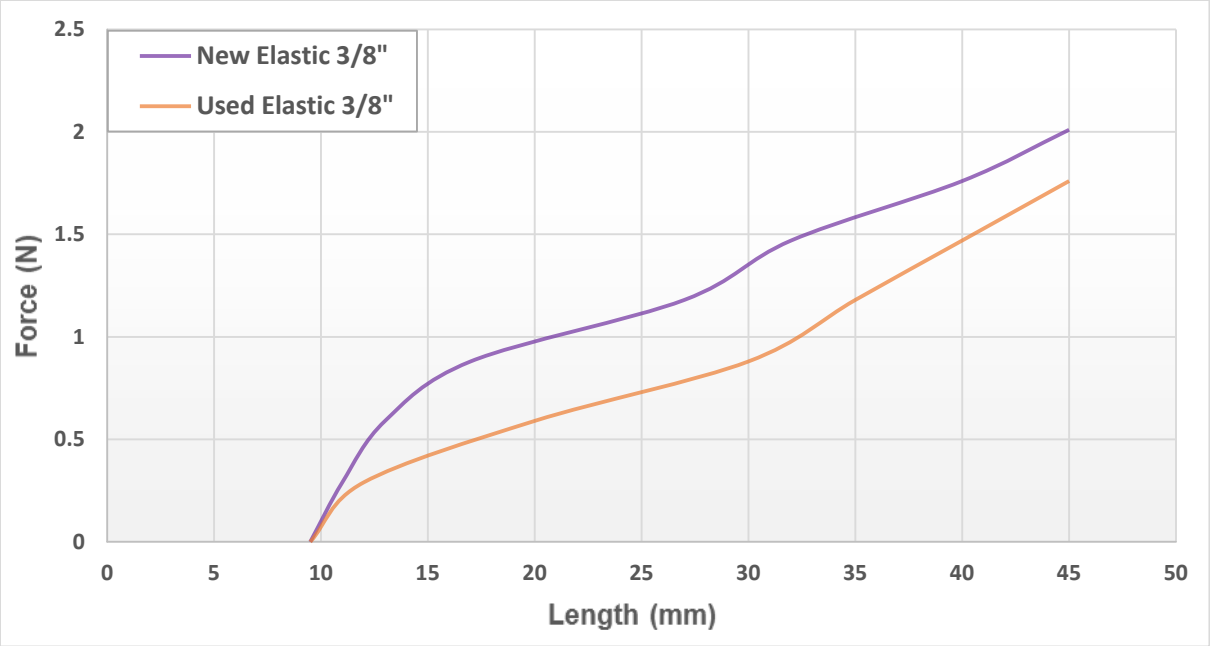

Figure (5): Curves showing the force applied in relation to the length of the 3/8 inch Ormco orthodontic elastics (new and used).

DISCUSSION

Latex elastics are widely used in intraoral appliances because they are flexible, have a low cost, are easy to handle and are able to return to their original form compared to non-latex elastics. However, elastics may undergo force degradation as well as change in their physical properties due to exposure to oral fluids and fluid absorption [(13)]. Elastics undergo greater degradation in humid environments compared to dry ones and are sensitive to changes in temperature [(12)].

Tensile tests were performed on ten new elastics and ten used elastics from each of three different sizes (1/4, 5/16 and 3/8 inch) which are commonly used in the presurgical orthopedic appliance. The used elastics were obtained from infants with BCLP using the presurgical orthopedic appliance for 3 days, to calculate the percentage loss of forces.

The elastics were stretched to 50 mm using the Mcmesin tensile testing machine. This was done following the studies that stated that used extensions of 20–50 mm, proposing it was the normal range for clinical use [(12)].

An index has been specified by several manufacturers to be used as a guide on the amount of forces delivered when the orthodontic elastics are stretched 3 times their diameter. This index may not be accurate [10,14].

The results obtained from this study allowed comparison of the forces applied when the elastics were stretched to 3 times their diameter with the forces stated by the manufacturer. The tensile tests showed that the forces obtained when the elastics were stretched 3 times their diameter, were less than the forces stated by the manufacturer by 5-7 %. This is comparable to the results obtained by Kanchana & Godfrey [10], and Oesterle et al [14], who stated that the force levels on the packs of orthodontic elastics were closer to stretching the elastic two times its lumen diameter.

However, the percentage difference in forces is not significant and therefore, the size of the elastic to be chosen for retraction of the premaxilla can be selected based on the force stated by the manufacturer by stretching the elastic 3 times its lumen diameter.

Regarding the percentage loss of the forces by the elastics for 3 days, the results of this study showed a 38.5- 42 % loss of the forces compared to the new elastics. The results are comparable to Kanchana and Godfrey [10], who stated that force degradation was highest during the first hour (29.9%) reaching 32.6% at 24 hours, then 36.2% at the end of the 3 day period. The force degradation then decreased gradually during the 3 day period. The results are also comparable to Yang et al [21] who stated that the force value decreased sharply in the first hour, but the rate of force degradation declined reaching around 30-40 % after 48 hours.

Fernandes et al. stated that the force values followed a straight line over the 12 to 24 hour period suggesting the change of orthodontic elastics every 48 hours [13].

CONCLUSION

The size of the orthodontic elastics used in presurgical orthopedic appliances for infants with bilateral cleft lip and palate can be selected based on the manufacturer's instructions which state that the force on the pack will be obtained when the elastics are stretched to 3 times the lumen diameter. The elastics can be used for 3 days to maintain a constant force to achieve retraction of the premaxilla. The elastics are then changed after the 3 days with new ones until the desired outcome is achieved.

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