EXPERIMENTAL ANALYSIS OF ORTHODONTIC ELASTICS UNDER PRE STRESSED LOADING

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Abstract. *Orthodontic elastics are used in several treatment technologies to correct malocclusions. In the most variable usages, those elastics should have uniform behavior, since no forecasted deformations may cause unexpected components of mechanical forces, that act in the dental movement. In this study, an experimental procedure to measure the elastic deformation submitted to constant loads was developed. The measures were performed using an acquisition and treatment of images system.Results of the stretching profile along the time of intraoral latex elastics, light, made in Brazil or imported were presented. It was made a test with a set of rings submitted of a pre-stretching to verify its stability of deformation compared with its initial relaxation. The same units, before pre-stretched and tested, were resting for more than 24 hours and, after that, stretched and measured under the same loads to compare the results with the one without rest, with objective to verify if there was any dimensional contraction. Suggestions are showed in sense of purpose better stability to the elastics, establishing guaranty standards of uniformities in their properties, and also more safety to the users.*

Keywords: *keyword 1, orthodontic intraoral elastics, pre-stretching, latex, acquisition and treatment of images system*

1. Introduction

Orthodontic elastics are used in several treatment techniques to correct malocclusion. In general, the professionals supply their patients with a certain amount of elastics for home replacement. The unknown of the relationship tension-deformation may lead to mistaken estimate of the amount of units needed to be changed and of the predicted time between changes.

The dental movement is due to tension application on the teeth, originating compatible tissue reactions to the inflammatory process, which unleashes the healing into a new bone remodeling situation. Then the fundamental importance of controlling any kind of anomalous interference, avoiding over-corrections which would result in an even greater organic effort to try to heal the involved tissues in the dental movement, with risks up to the dental element loss. As unpredictable deformations may occur, these elastics should have uniform behavior.

The biomechanic behavior of the periodontal band of connective tissue shows faster response when smaller tension strengths (from 49cN to 196 cN) are applied. Serious and permanent injuries can happen to the pulpar tissue because the remodeling and re-absorption processes as well as the consequent bones replacement are related to theses strengths, (Reitan, 1960). Ricketts (1988) considers that, in average, it is necessary a tension of around 98.0 cN/cm² of radicular surface faced, to lead to an appropriate movement into the regular physiologic standards. The specific dental movements should be held through biomechanic techniques where the used strength is considered step by step, minimizing radicular re-absorption (Wilheln, 1975; Szentpetery, 1993).

Some producers prescribe the elastics tension strengths when submitted to a stretch of twice or three times their internal diameter. Due to the orthodontic elastic own nature, its initial strength slumps along the time. An extra load, besides that which is necessary to move the teeth, is generally added aiming the clinic efficiency guaranty, although the excess can affect the tooth or dental elements involved in that movement.

A way to measure the elastics qualities is to submit them to the producer`s dimensioned loads and verify the degree and the stability of the strength under those constant loading. The measure acquisition of the intra-oral elastic strength submitted to a constant load along the time will show the elastic relaxation which corresponds to the initial strength slump.

This way, the professional will be able to control the strength to be used and check the results at every elastic change due to its degradation. The greater the initial applied strength by the elastic, the greater its degradation and the bigger percentage of strength loss and elastic degradation happens in the first hour of use.

In this study, it is presented a new methodology to the analysis of the orthodontic elastic deformation submitted to pre-stretching through an experimental evaluation, using and acquisition and image treatment system.

2. The orthodontic elastic

The orthodontic elastics are made of natural elastomer (latex) or the synthetic one. The qualities that enable its use in orthodontia are its great elasticity and flexibility. They are found in the market in several sizes, from 1/8" (3.2 mm) to 3/8" (9.5 mm) of diameter, and show variety in its thickness, for that being called light, medium, heavy and extra-heavy. The light elastics are from 49.0 cN to 73.5 cN; the medium ones are from 73.5 cN to 98.0 cN; the heavy ones are from 98.0 cN to 196.0 cN; while the extra heavy elastics are from 196.0 cN to 245.0 cN.

One of the polymeric most remarkable characteristics is the extreme dependence of its qualities to the time. The characterization of the orthodontic elastic mechanic behavior can be done by reaching or not the material rupture. While applying constant tension for a certain time on the elastomer, it is reached a slope of the deformation variation along the time. There will be an instantaneous response to the elastic deformation. When the loading is interrupted, there will be an elastic recovery of the deformation with a residual plastic deformation. Figure 1 shows, schematically, the behavior of the elastic deformation along the time.

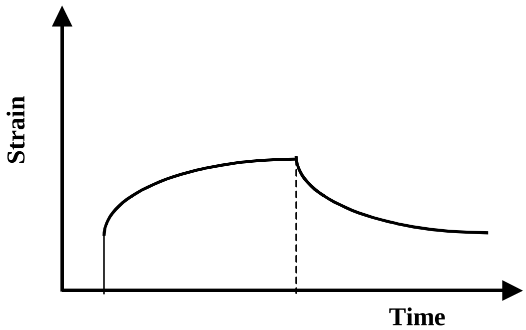

Figure 1 - Deformation slope (ε) according to the time (t) for the elastomer which was submitted to a constant load at a time interval and then interrupted.

The dental movement is related to the blood flow of the tooth periodontal band of connected tissue which suffers pressure. The greater the applied pressure on the tooth, the greater will be the blood flow reduction, until the vessels become totally collapsed and without blood flow in that region, which is the case of the heavy strengths.

When a light and extended strength is applied on a tooth, the blood flow, through the partially compressed band of connected tissue, diminishes as soon as the fluid is sent outside the periodontal area and the tooth moves in the alveolus in a few seconds. The change in the chemical environment, which happens at approximately four hours after these strengths are applied, results in a different standard of cell activity. This response is related to the use of removable brackets. If removable brackets are used for less than 4 to 6 hours, the orthodontic movement does not happen. Above this time the movement will happen.

For the tooth to move, the responsible cells for the bone`s removal (osteoclasts) should be formed to remove bones from the adjacent area compressed of the periodontal band of connective tissue. Though, considering the tension, the formation of the bones moulding cell (osteoblasts) is needed, as well as in the pressure areas on the side to be remodeled. After observing the increased periodontal area, the osteoblasts make bones on the side of the tension and the remodeling activity is started in the compression area (Nojima *et al.*, 1990).

The great strength to move teeth must be high enough to stimulate cell activity without obstructing the vessels of the band of connective tissue. The biological effect depends on the quantity of strength and on the area of the periodontal band of connective tissue where these will be distributed.

3. Methodology

To the analysis of the elastic deformation behavior along the time, tests were made with four elastic sets with internal diameter of 5/16 inches (7.94 ± 0.50 mm) of light intra-oral latex from a national producer and from an imported one as well.

The acquisition and image treatment measurement system in the visible and the image treatment process follow the methodology presented by Oliveira *et al.* (2003), with measurement uncertainty of 0.2 mm. This system has been created to reduce the dependence of the operator action and to guarantee better metrologic reliability, operation ease and low cost.

It was used a 58.8 cN of loading pattern, according to the light elastic specifications provided by the national and foreign producers. The images with the loads were captured from 10 to 10 minutes` time for an hour. For each elastic, as a first image, a minimum load of 12.7 cN was used, which stands for the weight of an empty bottle, to allow an initial stretching reference. The deformation measurement was provided by the difference between the measured and the reference values.

At the first stage, data from the deformations measurement test of the elastic without pre-stretching was obtained, aiming the evaluation of the elastic deformation directly from the producers` packages. There were tested four samples of national elastics and the same amount of sets of the imported samples. The deformation measurements were registered at every 10 minutes, along a one-hour sample, which allowed a deformation slope to be drawn according to the time.

At the second stage, it was aimed the elastic deformations stability verification according to its initial relaxation through tests of elastic sets submitted to pre-stretching. It was used a pre-stretching device made of a plain stainless steel tube of 23.82 mm of diameter (external measure), which corresponds to three times the elastic`s internal diameter; 3 mm of wall thickness by 150 mm of length, fixed orthogonally by a welding to the center of a disc- shaped base of 100 mm of diameter, produced in a 5 mm thick stainless steel plate. The testing bench is enough to stretch up to 25 samples of elastic rings set at around 5 mm distance. Figure 2 shows the pre-stretching testing bench that was made. The same units, which had been pre-stretched and tested before, were left in rest for over 24 hours and then tensioned again and measured under the same loads to compare to the measurement results with the one without rest, with the objective of verifying if there had been dimensional contraction. The tests happened in a dried off surface to compare it with the conditions that the product is received by the professional for its use.

Figure 2 - Cylindrical device for the elastic pre-stretching.

The third measurement stage consisted of making a new measure of the same eight national and imported elastic samples submitted to pre-stretching, which had been previously measured in rest, and then left without being submitted to any tension for a seven-day time. This procedure is called resting. Only after this period of time, the same measurement process was repeated with the same mentioned loads. The objective of this third measurement stage was to confront if a resting period after the pre-stretching would return to the pre-stretching condition.

4. Results

Figures 3 and 4 show, respectively, measurement results of national and imported latex elastic without pre-stretching.

From Fig. 3 results, it was observed a significant strain variety among the light national samples tested. The samples of this type of elastic, less resistant, widen from 29 to 42%. As the measures were taken at time intervals of 10 to 10 minutes, the results show that the stability of the relaxation happened between 30 to 40 minutes. At the 40-minute measurement, all the samples made evident that they had already completed the relaxation stage.

From Fig. 4, it was observed, as it was with the national elastic, that the light imported elastic also has significant modification of the strain characteristic from one sample to another. Although, the light imported elastic samples relaxed less, from 16 to 27%. The stability happened between 20 to 40 minutes. At the 30-minute measurement, three samples had already completed the relaxation and only one sample made evident the stability at the 40-minute measurement.

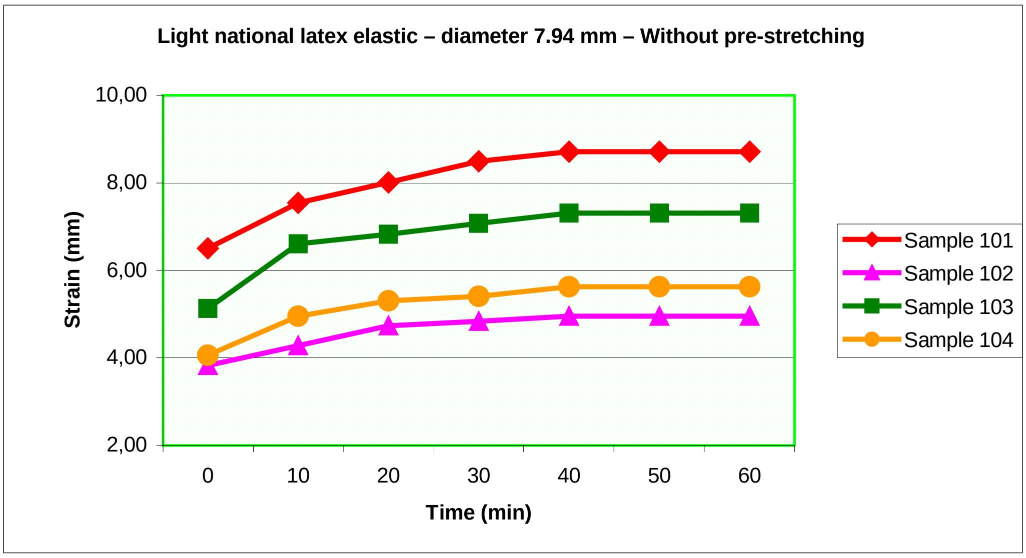

Figure 3: Graph Strain x Time of the light national latex elastic, without pre-stretching, submitted to a constant 58.8 cN load.

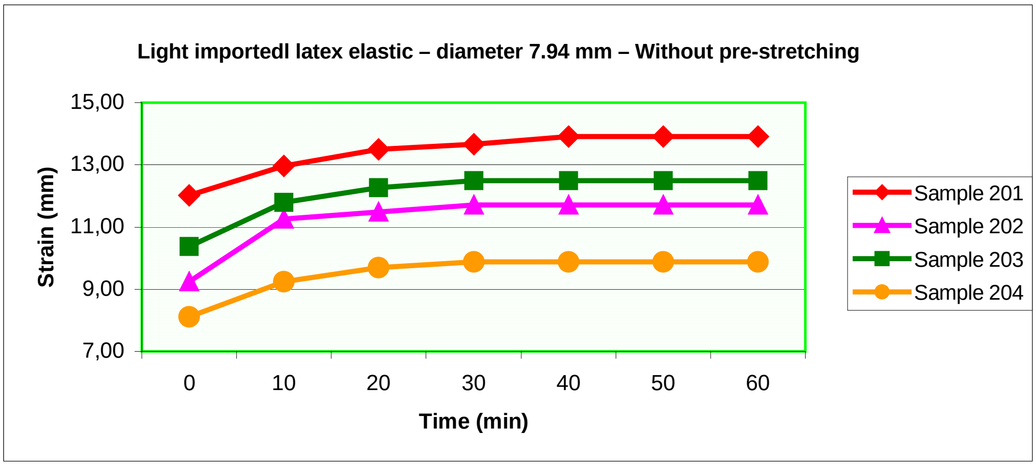

Figure 4: Graph Strain x Time of the light imported latex elastic, without pre-stretching, submitted to a constant 58.8 cN load.

The strain results according to the time of the pre-stretched elastics without rest are shown, respectively, at Fig.5 and 6.

From Fig. 5 results, the light national elastics pre-stretched without rest show tendency of smaller relaxation, from 3 to 12%. All the samples` stability happened in a shorter time, which was proved at the 10-minute measurement.

Figure 6 shows a dispersion in the light imported elastic samples pre-stretched without rest. The imported elastics submitted to pre-stretching without rest, as the national elastics, showed a small relaxation rate, from 2 to 3%, and all the samples completed the relaxation stage in a shorter time, which was verified at the 10-minute measurement.

If the initial time measurement is not taken into account, immediately after the load is applied and before the necessary time for the elastic accommodation, it is possible to deduce that the latex elastic, national or imported pre-stretched without rest, has not shown a sharp relaxation behavior in the first hour of use, differently of the elastics without pre-stretching.

The results of the deformation measurement set of national elastics pre-stretched with rest are shown, respectively at Fig. 7 and 8.

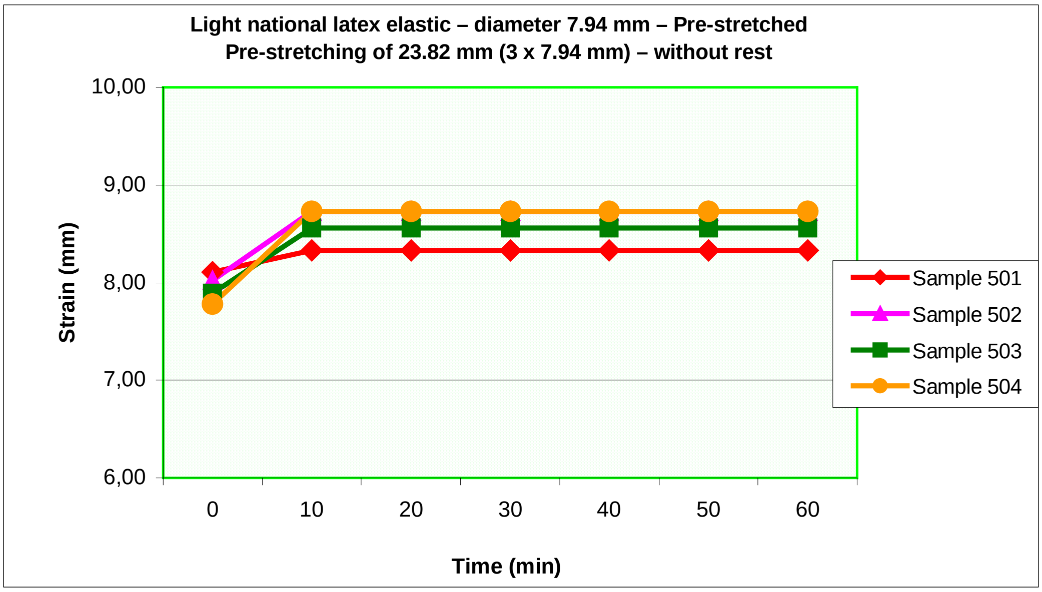

Figure 5: Graph strain x time of the light national latex elastic, pre-stretched, without rest, submitted to a constant 58.8 cN load

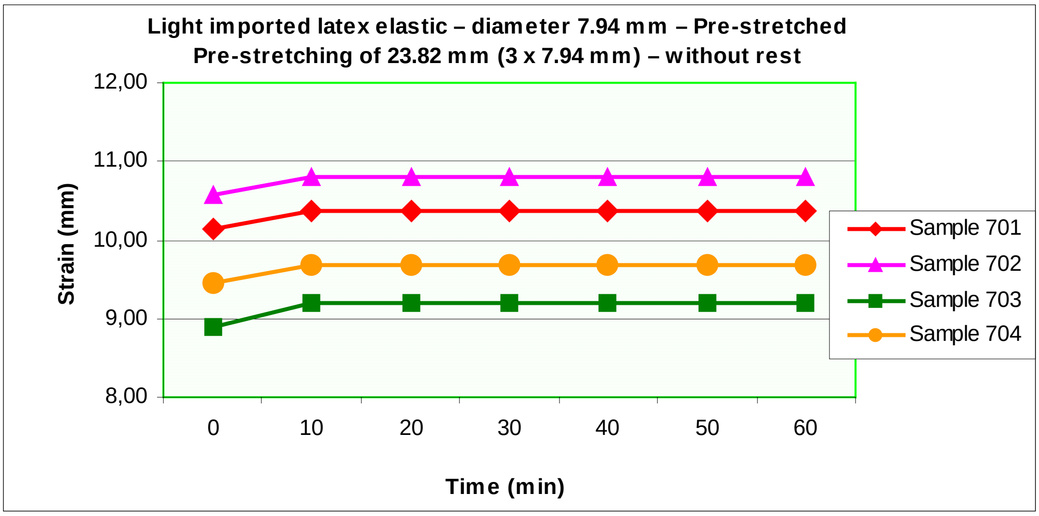

Figure 6: Graph Strain x Time of the light imported latex elastic, pre-stretched, without rest, submitted to a constant 58.8 cN load

Figure 7 shows a smaller result dispension in comparison to the results of the same samples measured immediately after the pre-stretching. It is assumed that because the elastics were kept for a long time in rest and without load, they recovered part of its original behavior. The relaxation rate was between 13 and 23%. The results show that the relaxation stability is found between 10 and 40 minutes. At the 20-minute measurement, one sample made evident that it had already completed the relaxation stage. At the 30-minute measurement, two samples were already stabled. Only one sample showed stability at the 40-minute measurement.

Figure 8 shows the resulting dispension of a test without rest. The relaxation rate was between 7 and 16% and it happened for a longer period of time, when three samples were shown stabled at the 30-minute measurement and only one other at the 40-minute measurement.

Table 1 shows the relaxation average rates of the light national and imported elastics from the tests without pre-stretching, with pre-stretching as well as without rest and without rest, and also with pre-stretching followed by a resting period.

Figure 9 shows a comparison of the average relaxation results among national and imported elastics. It can be reported that the rest after the pre-stretching led to a partially recovery of the condition previously without pre-stretching, with a consequent increase of the relaxation in relation to the previous condition without rest. However, there has been reached the registered relaxation values without pre-stretching.

It was found, from table 1 analysis, results consistence, both for the national and the imported elastic. As expected, the elastic after the pre-stretching shows smaller relaxation.

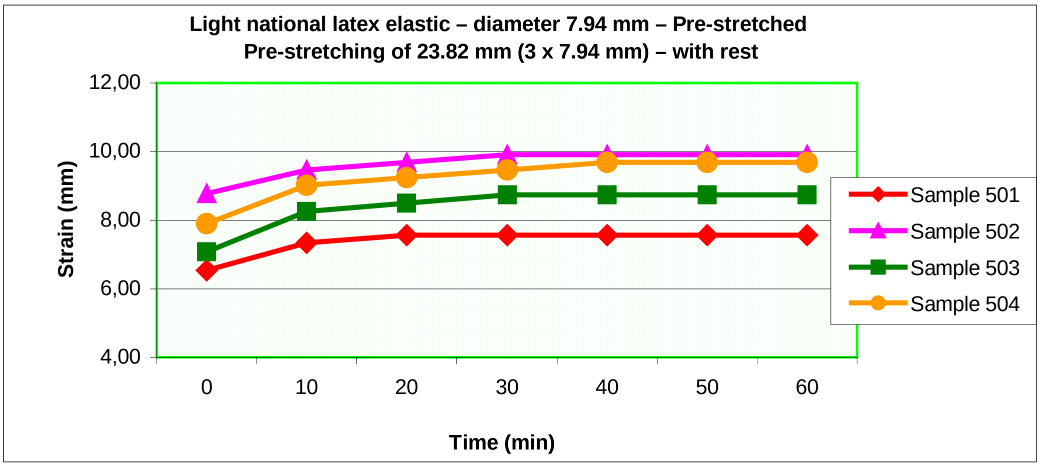

Figure 7: Graph Strain x Time of the light national latex elastic, pre-stretched, with rest, submitted to a constant 58.8 cN load.

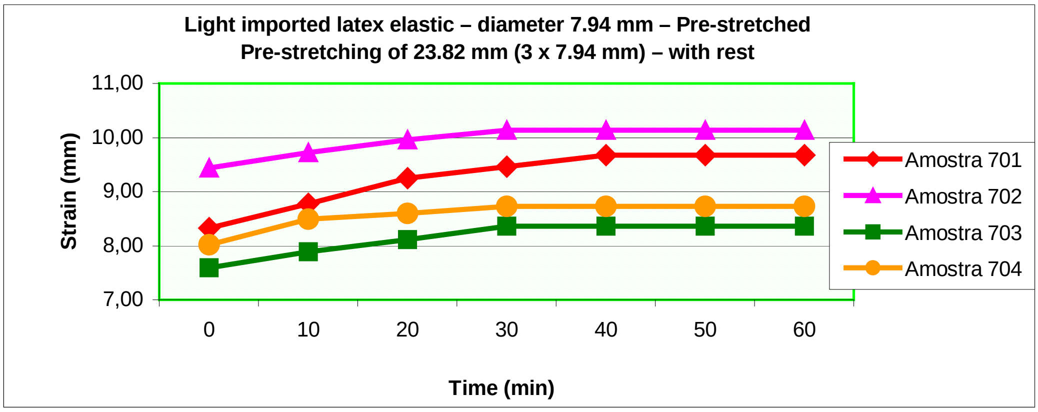

Figure 8: Graph Strain x Time of the light imported latex elastic, pre-stretched, with rest, submitted to a constant 58.8 cN load.

Table 1: Relaxation average rates of the light national and imported elastics, submitted to a 58.5 cN load.

KINDS OF ELASTICS	AVERAGE OF THE RESULTS (%) AND DEVIATION STANDARD (%)					
	Without pre-stretching		Pre-stretched without rest		Pre-stretched with rest	
	Average Strain	Standard Deviation	Average Strain	Standard Deviation	Average Strain	Standard Deviation
Light, national	36.1	5.0	8.1	3.4	18.7	4.5
Light, imported	21.2	3.9	2.6	0.5	10.7	3.4

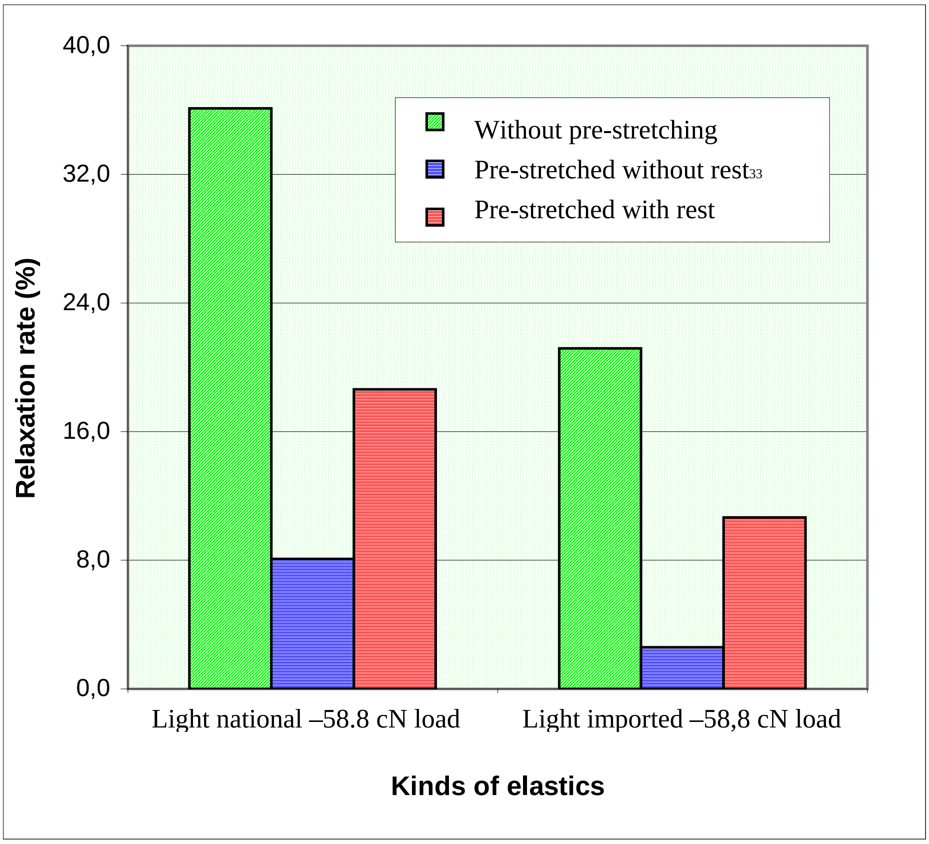

Figure 9 - Comparison of the average relaxation among national and imported elastics.

One of the explanations about this phenomenon is that, at the environment temperature, the elastomeric molecules assume a randomly wound configuration. However, under stretching, these molecules become partially lined up among each other. With the stretching tension removal, the molecules tend to return to their wound configurations and to their previous length (MacGregor, 1987). If the pre-stretching tension is kept for a certain time, the latex elastic does not return to its passive initial length. According to the same author, this happens because some molecules slip over each other for a longer tension period and do not return when the loading ends.

5. Conclusions

An experimental methodology was developed to analyze the deformation of orthodontic elastics submitted to pre-stretching. An acquisition and image treatment at the visible measurement system was used, with measurement uncertainty of 0.2 mm, and a pre-stretching device in cylindric shape, which provided a uniformed stretching through the whole elastic body. The device`s finish and the material used, stainless steel, contributed to the maintenance of the elastic integrity.

There were tested light intraoral latex elastics, national and imported ones, of 7.94±0.50 mm internal diameter. The loading standards used were of 58.8 cN, according to the producer`s specifications.

The images with the loads were captured at a time interval of 10 to 10 minutes for 1 hour. For each elastic, as the first image, a minimum load of 12.7 cN was used. The deformation measurement was obtained by the difference between the measured and the reference values.

The orthodontic elastic samples were directly taken for the packages and when tested, showed an initial relaxation followed by stability until 40 minutes, for both national and imported products. The stability period for the tested samples, between 30 minutes and 1 hour, were close to the reported values from the literature.

The tested samples from light national and imported elastics acquired fast stability when submitted to pre-stretching, in comparison to pre-stretched samples left in rest. After the rest, the samples showed a recovery of their previous condition without the pre-stretching.

There was demonstrated the proposed pre-stretching efficiency and the need of keeping this pre-stretching until the moment of the units use by the professional, which, as proved, reduce the initial strains at the critic period of the elastic stability.

The used methodology enables the professional to adjust the kind of elastic to be used according to the available distances to its fixation at the mouth and to the necessary mechanotherapy.

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