Effect of PH on the Degradation of the Elastic Chain during Orthodontic Treatment : An in Vitro Study

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Abstract

Objective: The aim of this study was conducted to measure the effect of PH on the degradation of the Elasomeric material and its effect on the inherent force decay over a period of time.

Material and Method: 20 3-link elastic chains of each product were selected at random from the spool. Out of this 20, 5 elastic chains were used for each of the 4 different PH solutions encompassing the range from acidic, to the normal range of oral PH. The forces were measured on an Instron Universal Tensile testing machine. Force was observed at 0 hour and following submersion in the four test solutions of 4.5, 5.5, 6.5 and 7.5 PH, at time intervals of 1 hour, 24 hours, 1 week, 2 weeks, 3 weeks and 4 weeks.

Results: It was found that the more acidic PH were kinder on the elastomeric chains with the less acidic or more alkaline PH being more hostile. This was reflected from the difference in the amounts of force decay of the chains in the different PH solutions. The decay of force was the least in PH 4.5.

Conclusion: This effect of PH gradually increases with time. It increases the rate of decay as the PH gets more alkaline, by simply being more hostile to the elastomeric chains.

Introduction

The state of the art of orthodontics spells out the state of the art of force application to bring about the desired changes to restore the physiognomy of the face. Numerous force delivering systems have been devised over the time. These include archwire loops, coil springs, sectional arch auxiliaries, latex elastics, and the later introduced elastomeric auxiliaries. The elastomeric chains are extensively used orthodontic armamentarium for intraoral use. These elastomeric chains return to their original dimension quickly, after being stretched to a limited deformation. This property is utilized to generate continuous force over a period of clinical use. Force decay due to degradation of the material is one of the inherent drawbacks of this material. The variables influencing force decay may be chemical from the saliva, food or oral hygiene products, thermal due to ingestion of hot and cold foods and mechanical due to mastication and oral hygiene procedures. Experiments have shown that the presence of orthodontic appliances in the mouth stimulates an environmental change characterized by a drop in PH, increase in food debris and number of bacteria especially streptococci and lactobacilli.

The main purpose of this study was to isolate a single aspect of the oral environment to facilitate analysis of its potential impact on the force decay rate of the chain elastics. The present study was conducted to measure the effect of PH on the degradation of the Elasomeric material and its effect on the inherent force decay over a period of time.

Material and Method

Two different commercially available polyurethane elastic chain products were tested for force degradation in different PH solutions (Sample A was TP orthodontics and Sample B was Ormco). 3 Unit links of gray chain elastics were stretched to a constant distance of 15 mm. For this purpose, jigs were made of acrylic blocks with stainless steel pins of O.060' diameter placed at a constant distant of 15mm. For the first readings, the elastics were stretched to a distance of 15 mm between the hooks on the jaws of an Instron tensile testing machine and for the rest of the duration of the experiment, the elastics were maintained in the stretched condition on fabricated jigs. During the experiment, no efforts were made to prestretch the elastics before activation or to stretch the elastics initially at an extremely slow rate. These factors were eliminated to reduce the number of variables involved, so that the effect of the test variable, PH, could be isolated. 20 3-link elastic chains of each product were selected at random from the spool. Out of this 20, 5 elastic chains were used for each of the 4 different PH solutions encompassing the range from acidic, as found in poor oral hygiene conditions, to the normal range of oral PH.

The test solutions were made by buffering distilled water with 0.26% sodium phosphate monobasic solution and 2.17% sodium phosphate dibasic heptahydrate solution and titrating 1M HC1 and 1M NaOH until the four desired PH were reached, i.e. 4.5, 5.5, 6.5 and 7.5. The test solutions were maintained in porcelain containers with glass covers to guard against evaporation and subsequent PH changes. Aluminium foil wrapping on each container was an added measure to prevent evaporation and PH changes. The test solutions were prepared 2 weeks in advance and monitored daily to determine PH stability. Acrylic blocks with elastics were then placed into test solutions for 1 week to monitor the PH stability of the test solutions before the elastic testing.

The forces were measured on an Instron Universal Tensile testing machine. (INSTRON, U.K.) The maximum load setting was calibrated to 500 gms with the range from 0 gms to 500 gms. Two .036' rigid wire hooks were clamped vertically in the jaws of the Instron machine. The cross head speed or travel was 10mm/mm. and the chart speed or travel was 20mm/mm. The elastics placed on the test jigs were kept submerged in the test solutions at all times during the course of the test except when force measurements were taken. These solutions were stored in an incubator that has been calibrated at 37 degree Celsius for the duration of the experiment.

Force was observed at 0 hour and following submersion in the four test solutions of 4.5, 5.5, 6.5 and 7.5 PH, at time intervals of 1 hour, 24 hours, 1 week, 2 weeks, 3 weeks and 4 weeks.

Results

From the study carried out, it can be inferred that all polyurethane elastic chains loose force with time after the initial stretch. The PH, of the four different test solutions, exerts an influence on the rate of force decay which is very clearly evident after 2 weeks of immersion in the solutions. This is indicated by a greater force decay in PH solutions of 7.5 as compared with PH 6.5 and 6.5 as compared with the other two PH i.e. 4.5 and 5.5.

Samples from Product A show an average force of 36.3 39.9% after one hour and 63.7 66.8% after 24 hours. Force decay further increased to 69 73.4% in the next two weeks. The effect of PH uptil now is not significantly evident. After 2 weeks it can be clearly seen that the decay in the more acidic PH i.e. 4.5 and 5.5 is less than the force decay in the less acidic solutions i.e. 6.5 and 7.5. After 21 days, i.e. 3 weeks this difference was found to be 4% in PH 6.5 and 5% in PH 7.5 more than those elastomeric chains placed in 4.5 and 5.5 PH solutions. After 28 days i.e. 4 weeks, the force decay in PH 5.5 was .5 ore than that for PH 4.5, in PH 6.5 it was 15.6% more and in PH 7.5, it was 16.1% more.

Samples from Product 'B' on the other hand show average force loss of 36.0 - 39.6% after one hour and 42.7 - 47% after 24 hours. The further decay in force in the next 2 weeks increased upto 47.3 52.4% after 24 hours. Similar to the previous sample, the effect of PH was evident after 2 weeks. Here too the amount of decay of force was 6.2% more in PH 5.5, 13.2% more in PH 6.5 and 16.9% more in PH 7.5 than that found in PH 4.5. This trend followed and after 4 weeks this difference increased to 8.9% in PH 5.5, 26.4% in PH 6.5 and 44.8% in PH 7.5.

Both these data clearly indicating that more alkaline or less acidic the PH, more hostile it is to the elastomeric chain elastics.

The reliability of the samples from product 'A' in the four different PH solutions, upto 3 weeks ranges from fairly good to very good. However, in the less acidic PH i.e. 6.5 and 7.5, due to the degradation of the polyurethane elastomeric elastic, the reliability drops to almost poor in PH 6.5 and

very poor in PH 7.5.

The samples from Product 'B' are found to be more consistent upto 3 weeks, with the reliability being very good. In this case, only the least acidic PH, i.e. 7.5, shows dramatic effects on the reliability of the chains causing a drop in the consistency to almost poor in the 3rd week and very poor in the 4th week.

It was necessary to know specifically the effect of one variable, i.e. PH, on the decay of force. Since both the Products A and B were not identical in terms of initial force values, comparative stiffness and further rate of decay, it was not possible to compare the actual force values. Therefore, Karl Pearson's correlation coefficient was computed to find the correlation between the two products, thereby eliminating all other variables and only understanding the effect of PH on the elastomeric chains. It was found that there is a positive correlation between the two products, with the effect of PH clearly showing more decay of force in less acidic PH solutions over a period of time, the effect increasing with the test time.

Discussion

Almost all 'philosophies' of orthodontics advocate application of force in some way or the other, according to the insight of the orthodontist. In fixed appliance therapy not all orthodontic forces arise within arch wires, coil springs and elastics too have a wide use. The great range of elastics available makes it possible to use any amount of force desired. The later introduced polyurethane polyesters have been found to excel in strength and resistance to abrasion when compared with natural rubber, providing an irritation-free system due to its smooth surface.

The force derived from chain elastics depends upon the magnitude of initial force, the length of time since activation and the rate of force decay, the first two factors being in the hands of the orthodontist and the third factor, being a combination of the inherent property of the material to exhibit decay and the effect of various variables present in the oral environment which influence this decay. As a result, in many a situation, the chain elastics may be applying an ineffective force for some period of time before the patient returns for the next scheduled visit.

Synthetic polyurethane elastomeric chains of two different commercially available products were taken, not to compare the, but to study the effect of PH on elastomeric chains which are of different makes, of different composition, stiffness and also imparting different initial forces for equal distance of activation.

These products were evaluated in the four PH solutions separately. The distance of activation, 15mm, chosen closely represents the distance between the attachment on the molar and attachment on the canine to which these chains would be affixed, in majority of the first premolar extraction cases after the unraveling of the anterior crowding present. This is not considering cases where there is bimaxillary protrusion or cases where no anterior crowding is present. Both the products were activated to l5mm stretch with the help of two hooks clamped in the jaws of the Instron tensile testing machine, preset to 15mm separation. When not on the hooks in the jaws, the elastic chains were maintained in a stretched condition on fabricated acrylic jigs.

The Instron machine has the capacity to stretch the elastomeric module to a certain distance simultaneously recording the force values exerted by the stretched chain. Instron was selected over the use of gauges for its reliability and accuracy.

The force degradation and the influence exerted by the PH was studied over a period of four weeks with readings taken at zero hours of initial stretch, on hour, 24 hours, 1 week, 2 weeks, 3 weeks and 4 weeks. This being in accordance with the fact that regular recall schedules are every 3-4 weeks.

From this study, it was also found that the maximum force degradation of the elastomeric modules occurred in the first 24 hours. This was followed by a lesser rate of decay over the next four weeks. Also, the more alkaline PH is more hostile to the elastomeric chains causing an increased rate of force degradation.

The percentage force degradation of sample from Product A was 71.7-76.8% after 3 weeks, the higher values belonging to the less acidic PH solutions i.e. 6.5 and 7.5. Samples from Product B exhibited 47.9-64.8% force degradation at 3 weeks here too the higher values belonging to 6.5 and 7.5 PH solutions. This force decay data, when compared to the earlier study, indicate that they can produce an effective tooth moving force throughout a 3 week period. It was only in the 4th week that the less acidic PH i.e. 6.5 and 7.5 decreased the force to lower than effective tooth moving force.

It can be concluded that the amount of force decay is influenced by the PH of the solution. This influence exerted by the four different PH solutions was not significantly evident in the first two weeks. Over the next two weeks, it was found that the PH of the test solutions markedly influenced the rate of decay which is clearly indicated by greater force loss in the more alkaline i.e. less acidic PH solutions of 6.5 and 7.5 as compared with the more acidic PH solutions of 4.5 and 5.5. It can thus be inferred that as the PH of the test solutions gets more alkaline, the more hostile they get to the polyurethane elastomeric chains. Degeneration of the elastomeric material because of the hostile alkaline PH resulted in failure of only one elastic in PH 7.5, leading to breakage just after the 20-second stabilization period. This could possibly be due to the quality of this randomly selected sample not being upto the standard.

The findings show that the consistency of Product A and B ranges from fairly good to very good for samples in PH 4.5 & 5.5. In the PH solutions of 6.5 and 7.5, the consistency was very good for the first 2 weeks, dropping in the 3rd week and presenting with highly irratic readings for the 4th week bringing the reliability to poor and very poor. Thus it can be said that the effect of PH is time dependent with the influence evident only after 2 weeks of immersion in the solutions.

From the above, it can be inferred that even though there is a decay of more than 50 percent of the initial force in the first day, there is only a gradual decline of force over the next few weeks. Starting with a force level only slightly higher than the optimal range, we are able to maintain the optimal force levels upto 2 weeks after which the force drops to an ineffective tooth moving force, however, remaining as an effective tooth holding force preventing relapse.

A clinician who wishes to have a continuous tooth moving force should therefore change the elastic chains every 3 weeks when the oral PH is more acidic and after 2 weeks as the PH becomes more alkaline.

Summery

A Study was carried out to understand the influence exerted by different PH values on the rate of force degradation of synthetic polyurethane elastomeric chains in vitro. Two different commercially available polyurethane elastomeric chains were used, differing not only in the make but also in physical properties such as ink size, distance between the chain links, stiffness of the material and the initial force values exerted for the same distance activated. Solutions of four different PH values i.e. 4.5, 5.5, 6.5 and 7.5 were used for the study. This encompassed the PH of the oral environment in poor oral hygiene conditions to the normal range of oral PH. The elastomeric chains were immersed in these four solutions for a time period of four weeks and readings were taken at regular intervals, on an Instron tensile testing machine, at zero hour of initial stretch, 1 hour, 24 hours, 1 week, 2 weeks, 3 weeks and 4 weeks.

The main purpose of this study was to evaluate

1. The rate of force decay of elastomeric chains over a test time period of 4 weeks.
2. The effect of 4 different PH solutions on this decay.
3. Degradation of the elastomeric material due to the PH of any particular PH solution.
4. Efficiency of the elastomeric chain to produce an effective tooth moving force over a 4 week test time period and the effect of the PH on the same.

40 elastomeric chains were evaluated in the 4 different PH solutions and a total of 280 readings were taken on the Instron tensile testing machine. From the observations and the findings of this study, it can be inferred that-

1. All synthetic polyurethane elastomeric chains evaluated in this study presented with a loss of force after the initial stretch.

2. The loss of force was dramatic, in both the products studied, within the first 24 hours. The two products exhibited a decay of 43-67% in the first 24 hours.
3. After this extreme rate of force decay in the first 24 hours, the decay continues at a relatively slower rate over the next four weeks. This further rate of decay being so slow that we can safely assume the force values to remain relatively constant after the initial extreme decay.
4. There is no significant effect of the four different PH solutions in the initial stages. The influence exerted by PH of solutions is evident only after 2 weeks, becoming more pronounced with time. This is clearly indicated by the striking difference in the values of force degradation, at the end of four weeks, of the elastomeric chains immersed in the four different PH solutions.
5. It was found that the more acidic PH were kinder on the elastomeric chains with the less acidic or more alkaline PH being more hostile. This was reflected from the difference in the amounts of force decay of the chains in the different PH solutions. The decay of force was the least in PH 4.5. This difference was found to be 4% more in PH 6.5 and 5% in PH 7.5 at 3 weeks, for chains of Product A. For the same chains at 4 weeks the difference was found to be 1.5% more at PH 5.5, 15.6% more in PH 6.5 and 16.1% more in PH 7.5. For sample of Product B at 3 weeks, PH 4.5 exhibited least amount of decay and when compared to the other solutions, the percentage of force decay was 6.2% more in PH 5.5, 13.2% more in PH 6.5 and 16.9% more in PH 7.5. At 4 weeks this difference increased to 8.9% in PH 5.5, 26.4% in PH 6.5 and 44.8% in PH 7.5.
6. The appreciable difference in the rates of force decay in more alkaline PH solutions especially of PH 7.5 is clearly indicative of the effect this PH has on the actual degradation of the elastomeric material which was responsible for the increased decay with time. However, we came across only one failure i.e. breakage of the chain elastic in PH 7.5 of a sample of the Product B.
7. Also considering the consistency of the two materials tested, it was found that by and large the elastomeric chains were consistent in force values and were reliable but as the effect of the PH crept in, associated with the degradation of the material, there was a fall in the consistency and the reliability dropped to fairly poor, poor and very poor, depending upon the PH i.e. 6.5 or 7.5 and also the time factor i.e. 3 weeks or 4 weeks.

Conclusion

It can be concluded that the synthetic elastomeric polyurethane chain produces an effective tooth moving force, which is significantly affected by the PH of the environment in which it is placed. This effect of PH gradually increases with time. It increases the rate of decay as the PH gets more alkaline, by simply being more hostile to the elastomeric chains.

Fig 1. Armamentarium

Fig 2. The two samples used

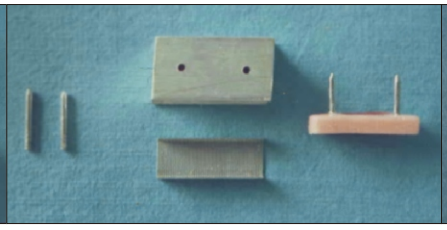

Fig 3. Method of fabrication of the acrylic jig

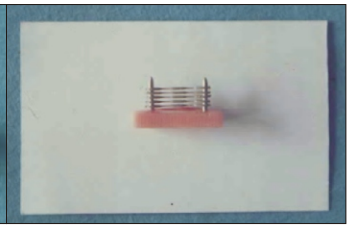

Fig 4. Acrylic jig with elastic mounted

Fig 5. Instron tensile testing machine

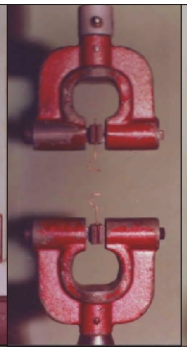

Fig 6. Hooks clamped in the jaws of Instron machine

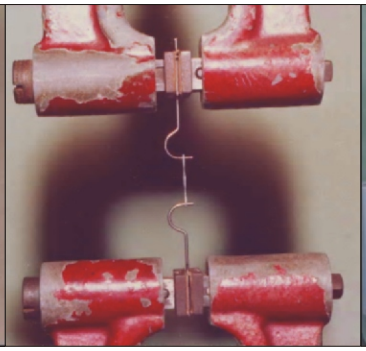

Fig 7. Elastic chain stretched at 15 mm separation between the hooks

Fig 8. Microtech 8823 digital PH/mV meter

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