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Changes in the force degradation of orthodontic elastomeric chains subjected to different formulations of chlorhexidine mouth rinse: An in vitro study

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Abstract---Introduction: The aim of this study was to assess whether various formulations of chlorhexidine mouth rinses had an effect on force characteristics of the elastomeric chains. Methods: The sample consisted commercially available elastomeric chain of 3M Unitek with five commercially used chlorhexidine mouth rinses of different formulations. The e chain were stretched on artificial saliva .30 sec everyday exposure to different chlorhexidine formulation was tested by digital dynamometer and was statistically evaluated using ANOVA test. Conclusion: mouthwashes does not accelerate force degradation of elastomeric chains which could clinically affect their effectiveness. However, the results could be variable in the presence of other

biological factors in the oral environment and their interactions between oral microorganisms with the host.

Keywords---orthodontic elastomeric, chlorhexidine, formulations.

Introduction

Over the years orthodontists have relied on various force delivery systems to achieve tooth movement. Contemporary orthodontics advocates the use of light forces. The use of elastics in orthodontics can be traced as far back in the year 1841 by JMA Strange, a Frenchman who claimed that he used a rubber attached to some hooks on the appliance surrounding the molars for retention.¹ Farrar in 1876 mentioned the use of rubber bands in appliances, and then Calvin S. Case in 1893 had mentioned the use of elastics in orthodontics. However, after Henry A Baker mentioned the use of elastics to exert Class II intermaxillary force (Baker's Anchorage), the use of elastics in orthodontics gained immense popularity.¹

Synthetic elastomeric chains were introduced as an alternative to the latex elastic bands. Elastomeric chains are economical, easy to use, relatively hygienic, comfortable and swell less than the latex material. The synthetic elastomeric materials have also been found to be relatively compatible with the mucosa. These factors have contributed to a high degree of professional acceptance of the chain elastics in orthodontics Arch wire loops, coil springs, latex elastics and synthetic elastomers are the materials which are used in an orthodontic office to apply forces to move teeth. They are the basis for orthodontic tooth movement.² These have been widely used in Orthodontics since 1960s and their effects have been evaluated since then.³

The elastomeric chain polymers are not ideal elastic materials for their mechanical properties and are dependent on environmental factors like different solutions, time, temperature and thermocycling method etc. Unfortunately, like all other elastic materials, the forces delivered by elastomeric chains are also not constant and degrade over time. The degradation is because of molecular chain stretching, slippage between adjacent molecular chains, and molecular chain scission.

The force degradation of the elastomeric chains is a major problem a clinician faces in day to day clinical practice. Elastomeric chains, when stretched and exposed to oral environment absorb humidity through water, saliva and food debris and suffer a breakdown of 5 internal bonds due to stress relaxation which leads to permanent deformation and gradual loss of its effectiveness.⁵

As orthodontic treatment with fixed appliance alters the oral environment, there is an increased accumulation of plaque around the bands and brackets.⁶ Microbial accumulation on the tooth surface adjacent to brackets ligated with elastomeric ligatures, does not allow archwires to completely seat during torquing and rotational correction.⁶ Poor oral hygiene is a major concern during orthodontic treatment. It is important to implement chemical plaque control in patients who are unable to maintain good oral hygiene. Among the antimicrobial agents for oral use, chlorhexidine is one of the most effective and commonly used mouthrinses.⁶ Chlorhexidine acts in a preventive manner in reduction of bacterial

plaque in patients undergoing Orthodontic treatment. Chlorhexidine is a bis - biguanide agent with the antibacterial properties, having a special affinity for the oral structures and presents a high level of activity.

Several studies have investigated the force degradation of orthodontic elastics as a result of different pH, different artificial saliva formulations, different temperature, varying alcohol concentrations in mouth rinses, have been performed.^{8,9} Nevertheless there is no information about the effect of varying concentrations of commercially available chlorhexidine mouth rinses on the force degradation of the orthodontic elastomeric chains. Therefore, the aim of this study was to assess whether various formulations of chlorhexidine mouth rinses had an effect on force characteristics of the elastomeric chains.

Materials and Methods

The sample for this in-vitro study consisted of:

1. A commercially available orthodontic elastomeric chain (continuous) of 3M Unitek manufacturer. The elastomeric chains were divided into five experimental groups and one control group of 20 elastomeric chains each. Thus the total sample taken was 120 elastomeric chains.
2. Five commercially used chlorhexidine mouth rinses of different formulations.
 - 0.1% Chlorhexidine gluconate (Eludril Mouth rinse). □ 0.12% Chlorhexidine gluconate (Periogard Mouth rinse)
 - 0.2% Chlorhexidine gluconate (Clohex Mouth rinse)
 - 0.2% of Chlorhexidine gluconate with 0.05% Sodium fluoride and 0.09% Zinc Chloride (Clohex Plus Mouth rinse)
 - 0.2% of Chlorhexidine gluconate with 0.05% of Triclosan and 0.07% of sodium monofluorophosphate (Rexidin Plus Mouth rinse)

Six specimen groups were tested with a total sample size of 120 specimens. A specimen is described as seven link clear elastomeric chain of 3M Unitek Manufacturer (Figure 1). Acrylic sheets measuring 15cm X 15cm X 1cm were fabricated. The sheets consisted of two rows and 10 columns of 40 stainless steel pins of 0.040 mm diameter. The stainless steel pins were stabilized 50 mm apart and were used to hold the stretched elastomeric chains at constant length.

Methodology

The control and the the control and test groups were independently submerged in separate, 37°C artificial saliva, in order to simulate the oral conditions. **Artificial Saliva** used in the study was made using Diastase Powder and distilled water. 10 gms of diastase powder was mixed with 1000 ml of distilled water. It was housed in an incubator and maintained at room temperature using thermostat. The control group was submerged in Distilled Water Similarly the test specimens were submerged in the respective test solutions i.e. Eludril, Periogard, Clohex, Clohex Plus, Rexidin Plus for 30 seconds , twice daily for the entire test period.

Each 30 second exposure of the test specimens was measured using a digital clock, and the two daily exposures were separated by 12 hours. After being submerged in the respective solutions, specimens were dipped in separate, distilled water baths for 10 seconds to simulate rinsing of the mouth rinses from the oral cavity. These specimens were then placed back into artificial saliva at 37 °C. The control group underwent the same protocol; however, these elastomeric chains were only exposed only in distilled water.

Six test measurements of the remaining force values were made at the following time intervals:

initial (0), 1, 7, 14, 21, and 28 days. Force measurements were obtained with a Digital Dynamometer. Measurements were made by leaving one end of the elastomeric chain secured on the pin and fixing the other to the force tester, allowing for the measurement of the tensile force.

Measurement readings were taken with the elastomeric chain stretched to the same 50 mm length that the jig pins had previously maintained them. All chains were handled and measured in the same manner at the same vertical and horizontal distance on the jig board to ensure consistent measurements.



Elastomeric chain of 3M Unitek manufacturer



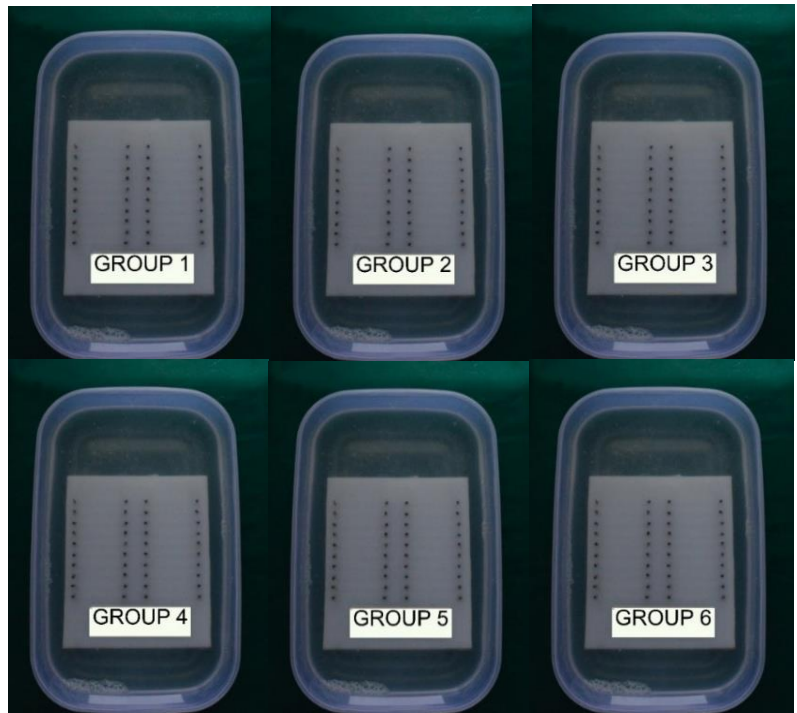
The Jigs with stretched Elastomeric chains dipped in artificial saliva



MOUTHWASHES USED



THE JIGS IN INCUBATOR



Digital dynamometer

Results

In this experiment there are two factors influencing force decay of elastomeric chains, which is time duration and exposure to test solutions. The factors and their levels are tabulated below:

Intergroup comparison of degradation of tensile strength of elastomeric chain from day 0 to day 28

One Way Anova Test with Tukey Posthoc Test

Groups	N	Mean	Standard Deviation	P Value
Group 1	20	327.85	3.281	<0.001*
Group 2	20	315.5	2.763	
Group 3	20	316.5	4.007	
Group 4	20	306.1	3.892	
Group 5	20	303.6	5.345	
Group 6	20	305.7	4.485	
Total	120	312.54	9.352	

Intergroup comparison using One Way Anova Test with Tukeys Posthoc Test shows that there is significant difference in the mean tensile strength of the elastomeric chain.

According to table 1,2,3,4,5,6 along a period of 28 days Clohex Plus(0.2%) showed least amount of force degradation followed by Rexidin Plus, Clohex, Eludril and Periogard.

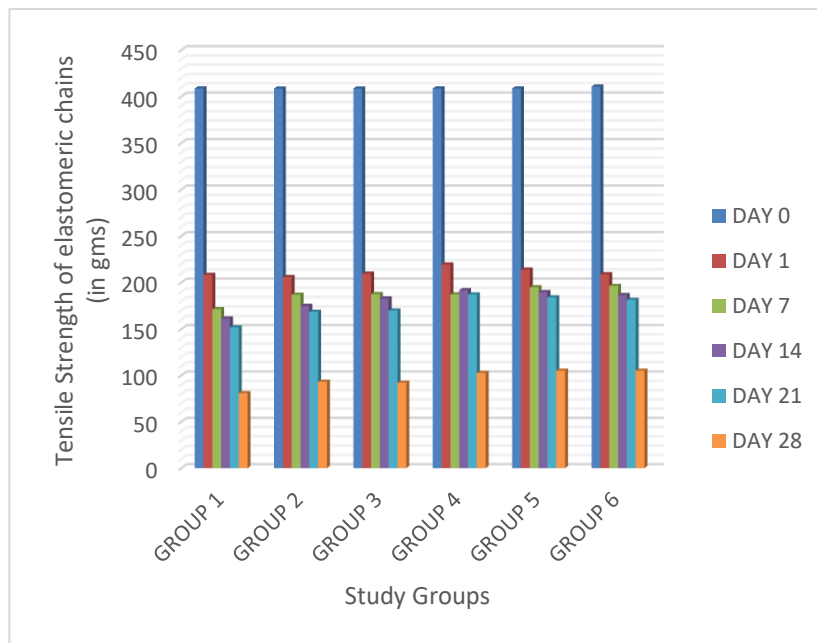
Control Group showed highest amount of force degradation.

Groups compared in the same time interval and the P value for each day using One Way Anova for each time period comparison of 6 groups.

When the groups were compared in the same time interval and the P value for each day using One Way Anova for each time period comparison of 6 groups were calculated it showed that it is statistically significant.($P < 0.001$)

Intergroup Comparison of force degradation from Day 0 to Day 28

	GROUP												F	P VALUE
	GROUP 1		GROUP 2		GROUP 3		GROUP 4		GROUP 5		GROUP 6			
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation		
DAY 0	408.60	1.82	408.50	2.35	408.50	2.35	408.60	1.82	408.60	1.82	410.70	2.32	3.487	<u>0.006</u>
DAY 1	208.10	2.75	205.75	4.94	209.40	.94	219.25	2.45	213.75	2.22	208.75	3.19	52.933	<u><0.001</u>
DAY 7	171.25	2.75	186.75	2.45	187.50	3.03	187.20	39.64	194.75	1.12	196.25	2.22	5.902	<u><0.001</u>
DAY 14	161.25	2.22	174.75	2.55	182.75	4.72	191.75	2.45	189.50	.89	186.40	3.20	306.804	<u><0.001</u>
DAY 21	151.75	2.45	168.50	1.54	169.75	1.12	187.10	1.41	184.00	2.05	181.30	3.20	800.281	<u><0.001</u>
DAY 28	80.75	2.45	93.00	2.51	92.00	2.51	102.50	2.56	105.00	5.13	105.00	4.59	152.458	<u><0.001</u>



Intergroup comparison of force degradation from day 0 to day 28 shows that there is gradual decrease in the tensile strength from Day 0 to Day 28 shows that there is sudden decrease in the tensile strength at Day 1(almost 50%) followed by gradual decrease till the end of 28 days. Greatest amount of force degradation was seen at the end of 28th Day in all group.

Discussion

Elastics made from natural rubber continue to be in common use in orthodontics, mainly because of their favorable characteristics of high flexibility and low cost. Elastomeric chains are used as the retractive force to move teeth into extraction sites, closing diastemas, generalized space closure and correction of rotated teeth. The chains serve as ligatures to tie the arch wire to the bracket. The elastomeric material provides irritation free system due to its smooth surface. Therefore it does not have the problem of tissue irritation, as ligature wires do when they become protruded.

Elastomeric chains, however, are not without their disadvantages. When exposed to an oral environment, they absorb water and saliva, permanently stain, and suffer breakdown of internal bonds leading to permanent deformation¹⁸. They also experience rapid loss of force due to stress relaxation, resulting in a gradual loss of effectiveness¹¹. Clinical observations have shown that the elastomeric materials are permanently elongated and undergo plastic deformation. This deformation is related to the amount of time as well as the amount of stretch given to the materials. This means that the orthodontist must have a sound knowledge regarding the property of plastic deformation and the factors influencing it, in order to enable him to best select the most suitable elastic chains for the required clinical purpose.

The oral hygiene problems have not been completely eliminated because there is greater bulk of material around the bracket when compared with the wire ligature. Use of orthodontic appliance demands that the wearer take special care because the presence of this device in the oral cavity leads to greater accumulation of the bacterial plaque around the brackets and bands. Considering that deficient oral hygiene generally is a reason why it is difficult to achieve successful orthodontic treatment, it is necessary to implement an individualized model of preventive education for each patient. In individuals who cannot or are unable to perform good oral hygiene in addition to mechanical control it is important to implement chemical plaque control also.

Among antiseptics for oral use, Chlorhexidine is one of the most powerful and most studied antimicrobials but has its disadvantage of staining teeth. In previous studies, mouthrinses have been used to test force degradation of elastomeric chains but there has been no study conducted to test the effect of various concentrations of chlorhexidine which are commercially available. Hence in this study, five commercially available chlorhexidine mouthrinses with different concentrations were used to determine its effect on force degradation of elastics over a period of time.

Since the 1970's, several studies have been published on the decay of elastomers in the oral cavity during orthodontic treatment¹¹. The results of various studies on orthodontic elastics have shown wide range of force decay (24% - 85%) after 28 days. Some of the reasons behind these results may include difference in the media in which the samples were tested and quality of the elastomeric chains used.

Years ago, De Genova et al.³ evaluated the behavior of elastics over a period of 3 weeks. However, a period of 4 weeks was selected for the study because it coincides with the time interval between orthodontic consultations, the same period was observed by Motta et al.⁴². Another factor that influences mechanical behavior is the size of chain elastics—described as short, medium, or long. In this study, the continuous chain elastics, without spaces between the links, was adopted, since they maintained a higher percentage of force over the course of time.

Because this present study concerns a simulation of the oral cavity, the temperature at which the elastics were maintained was $37 \pm 1^\circ\text{C}$ and also because it is known that the temperature participates in the force degradation of the elastics³¹. Bishara and Andreasen in 1970 stated that no significant difference in force degradation of elastomeric chains existed when materials were tested in water or in saliva¹¹. Artificial saliva has been used as a medium in other studies also done by De Genova³, Pithon⁶ and Larabee⁹. Therefore, the chain elastic segments were kept immersed in artificial saliva. In this study the force was measured using a Digital Dynamometer.

A Dynamometer or Dyno for short is a device which is used for measuring force, torque or power. The dynamometer used in this study is the Precision Portable Digital Force Dynamometer. The range of the Dynamometer is 10kg/10gm, 20 kg/10 gm.

The module lengths of 23.5 mm of elastomeric chains used in this investigation were selected because they represented maximum stretch that a clinician might use to retract a canine into the space of an extracted first premolar. Since the study was conducted to test the maximum force decay, maximum stretch of elastomeric chain was used. The wide range of initial forces produced ie; 240.8 gm to 436.0 gm (236.14 cN to 427.56 cN) is higher than the range of optimal force for retraction ie; 100 gm to 250 gm (98.06 cN to 245.16 cN) suggested by Storey and Smith.¹¹

Based on the results obtained in this study, the mean initial force value of different specimens at 50 mm extension ranged from 410-415 gms, which is higher than the ideal orthodontic force and there was a force decay of 50% within 24 hours. An optimum residual force of 80-105 gm was present till the end of 28 days.

The optimal force required for canine retraction as stated by by De Genova DC et al³, Eliades et al²² in their studies was 100 gms - 250 gms. However, a study by Andreasen GF and Bishara S found that the initial force degeneration of elastomeric chains on the 1st day was approximately as 74% and hence they suggested that clinicians may have to apply nearly four times the desired force to compensate for this loss.¹² Thus, from a practical point of view, the force levels in our study were kept high in view of this inevitable loss of force that would have occurred during the entire test period.

During the study, initial (0 day) tensile strength was recorded for the control group and five experimental groups for elastomeric chains. The force exerted by the elastomeric chains in Distilled water(Group 1), Eludril Mouthwash(Group 2), Periogard Mouthwash(Group 3), Clohex Mouthwash(Group 4), Chlorhex Plus Mouthwash(Group 5), Rexitin Plus(Group 6) were between 400 to 415 gms. A similar study was carried out by Larrabee TM et al⁹ showed initial force level ranging from 514 gms to 521 gms which were much higher compared to our study which could be due to the difference in the length, material of the elastomeric chain and due to the difference in the media like distil water, 14% alcohol, Listerine, Cepacol and 26.9% alcohol used.

Among all the experimental groups, it was observed that the force degradation of Elastomeric chains was least in Chlorhex Plus mouthwash followed by Rexitin Plus mouthwash, Chlohex mouthwash, Eludril mouthwash and at last is Periogard Mouthwash which shows highest percentage of force degradation. The findings of our study was similar to that of Pithon M et al whose study also concluded that 0.12% of chlorhexidine group showed highest values of decline in force and Control group had lower force value than the Chlorhexidine groups.⁶

In the 0.12% Chlorhexidine group(Periogard mouthwash) showed highest percentage of force degradation. A similar study conducted by Pithon M et al using Periogard(0.12%) showed that it exhibited highest percentage of force degradation.⁶ In the 0.1% Chlorhexidine group(Eludril Mouthwash), the elastomerics showed more degradation of force than compared to Clohex mouthwash, Chlorhex mouthwash and Rexitin Plus mouthwash. In this study it

was observed that there was significant difference in the force degradation in the five experimental groups.

The mean tensile strength at each time interval from Day 0 to Day 28 for Group 1(Control Group-using Distilled Water) ranged from 408.6 to 80.75 gms with a standard deviation of 2.44. The mean tensile strength at each time interval from Day 0 to Day 28 for Group 2(Experimental Group-using Eludril Mouthwash) ranged from 408.1 to 93 gms with a standard deviation of 2.33.

The mean tensile strength at each time interval from Day 0 to Day 28 for Group 3(Experimental Group-using Periogard Mouthwash) ranged from 408.5 to 92 gms with a standard deviation of 1.99. The mean tensile strength at each time interval from Day 0 to day 28 for Group 4(Experimental Group using – Clohex Mouthwash) ranged from 408.7-102.5 gms with a standard deviation of 1.5. The mean tensile strength at each time interval from Day 0 to day 28 for Group 5(experimental group using –Chlorhex Plus Mouthwash) ranged from 408.6-105 gms with a standard deviation of 1.5. The mean tensile strength at each time interval from Day 0 to Day 28 for Group 6(experimental group using – Rexitin Plus Mouthwash) ranged from 406.6-103.5 gms with a standard deviation of 1.3.

When the groups were compared in the same time interval for Day 0 to Day 28, Day 0 mean for group 1 to 6 showed a P value of 0.001 which is statistically significant. For Day 1 to Day 28 at each time interval mean for group 1 to 6 showed a P value of 0.001. Mean difference of tensile strength of elastomeric chain at each time interval from day 0 to day 28 for GROUP 1(Control group using Distilled Water), GROUP 2(Experimental group using Eludril Mouthwash), GROUP 3(Experimental Group using Periogard Mouthwash), GROUP 4(Experimental Group using Clohex), GROUP 5(Experimental group using Chlorhex Plus Mouthwash), GROUP 6(Experimental Group using Rexitin Plus) showed significant difference with a P value of <0.001. This is the first known study using various concentrations of commercially available chlorhexidine mouthwash in which it was observed that Clohex mouthwash shows least amount of force degradation as compared to the other mouthwash which were Eludril, Periogard, Chlorhex plus, Rexitin Plus). The control group in this study showed highest percentage of force degradation than other experimental groups. This result is in accordance with a study done by Python M where during a interval from Day 0 to day 28 there was highest amount of force degradation.⁶ Intergroup comparison of degradation of tensile strength of elastomeric chain from day 0 to day 28 using One Way Anova Test with Tukey Posthoc Test showed a significance of 0.001.

Multiple group comparison of total degradation of tensile strength (Day 0 to Day 28) also showed a significant difference of 0.001 except for group 2-group 3 when we compare them and group 4 -group 5 and group 5-group 6 which showed a significant level of 0.970, 0.371 and 0.573 respectively.

In this study, we evaluated different types of chlorhexidine mouthwashes available commercially along with most commonly used elastomeric chains in orthodontic practice. Natural conditions were simulated as much as possible by using artificial saliva and simultaneously in order to simulate the oral temperature, an Incubator maintained at 37°C was used. A study conducted by

Stevenson JS and Kusy RP have shown that increase in temperature appears to be the dominant single factor in force degradation of elastomeric chains.

Although this study illustrates that the media used have a statistically significant effect on the force decay of elastomeric chain in vitro, its impact in clinical situations is still inconclusive. On 28 days the control group (Distilled Water) had forces ranging between 70-85 gms of force remaining and the average amount of force remaining for the test groups ranged between 90 gms to 120gms. This explains that the mouthwashes have a significant effect on the force degradation of elastomeric chains, which could be due to various ingredients present in the mouthwashes and due to the composition of the elastomeric chains. In our study it was observed that mouthwashes does not accelerate force degradation of elastomeric chains which could clinically affect their effectiveness. However, the results could be variable in the presence of other biological factors in the oral environment.

Further laboratory studies should simulate the clinical conditions of the oral cavity to determine the effects of changes in pH, temperature, intake of food, beverages, contaminants etc on the tensile strength of the elastomeric chains. Since the study was done under static condition in vitro, the performance of the elastomeric chain could not simulate the degradation seen in-vivo. Further studies needs to conducted in clinical situation, where varied oral environment due to different dietary habits, microbial activity and stretching is present. This would allow us a better understanding of the physical properties of elastic materials under clinical conditions. Further study is needed using different brands of elastomeric chains. This would help to determine whether the results of this study are comparable to what might be seen on a larger scale among different manufacturers. Therefore, although the present findings are a useful guide to the anticipated clinical behavior of the elastomeric modules, the observed clinical behavior may differ.

Conclusion

The force degradation was least in Clohex Plus followed by Rexitin Plus, Clohex, Eludril and was highest in Periogard. Force degradation was more in control group at the end of 28 days. It is thereby concluded in our study that mouthwashes does not accelerate force degradation of elastomeric chains which could clinically affect their effectiveness. However, the results could be variable in the presence of other biological factors in the oral environment and their interactions between oral microorganisms with the host. Duration was found to be the most important factor in influencing force decay followed by solution. The force degradation was rapid in first 24 hrs. followed by gradual degradation over the next 21 days and then decreased again in next 28 days.

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