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Research Article

AN INVITRO EVALUATION OF CORROSION OF STAINLESS STEEL ORTHODONTIC BRACKETS BY CHANGE IN MASS: INFLUENCE OF DIFFERENT TOOTHPASTES

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A B S T R A C T

Introduction: Stainless steel brackets are widely used in orthodontics because of its affordability, mechanical properties, strength and biocompatibility. Among all the components of fixed appliances, brackets are subjected to fluctuations in the oral environment like dietary habits, different oral hygiene practices performed. Previous studies have showed that around 70% of Indian population use toothpastes as common oral hygiene practice technique. In addition to this, orthodontists prescribe different fluoride containing toothpastes during orthodontic treatment. As brackets will be in close association with the toothpastes more than other components, it is very much necessary to evaluate the effectiveness of different toothpastes on the corrosion of stainless steel brackets.
Aims & objectives: To assess corrosion by measuring the change in weight of stainless steel brackets before and after immersion in toothpastes using digital analytical balance.
Materials & method: Thirty six MBT 0.022″ slot stainless steel brackets were randomly divided into 3 subgroups of n = 12. The brackets in Group 1 were subjected to Colgate® Total® 12 Toothpaste solution prepared by mixing with artificial saliva at a 1:4 (w/v) ratio. The brackets in Group 2 were subjected to Close Up Deep Action Toothpaste solution prepared by mixing with artificial saliva at a 1:4 (w/v) ratio and the brackets in Group 3 were subjected to GC Tooth Mousse solution prepared by mixing with artificial saliva at a 1:1.14 (w/v) ratio. pH of all the test solutions and toothpastes were individually evaluated on a digital pH meter. The brackets were weighed on a digital analytical balance before immersion in test solutions. The immersion time for the brackets will be 48 hours [simulating the total recommended tooth – brushing time (2 min, twice a day for 2 years) i.e., duration of average orthodontic treatment]. The samples were rinsed with 100ml of distilled water and air dried. All the brackets were weighed again after the immersion in test solutions on a digital analytical balance. Corrosion of the brackets were measured by the change in the weight of the brackets using digital analytical balance.
Results: Among the three groups, weight loss of the brackets immersed in Close Up Deep Action Toothpaste, followed by brackets immersed in GC Tooth Mousse, the least weight loss was seen in those immersed in Colgate® total® 12 toothpaste.
Conclusion: From this study it was concluded that weight loss of the brackets immersed in Close Up Deep Action Toothpaste was the highest owing to the acidic pH of both the toothpaste and the prepared test solution, followed by brackets immersed in GC Tooth Mousse owing to the neutral pH of both the toothpaste and the prepared test solution, the least weight loss was seen in those immersed in Colgate® Total® 12 Toothpaste owing to the basic pH of both the toothpaste and the prepared test solution.

INTRODUCTION

Modern orthodontics uses a variety of appliances and devices to achieve the requisite degree of tooth movement, which includes metallic, plastic, or polymeric and ceramic brackets[1].

Brackets are subject to corrosion in the oral cavity because they are immersed in the patient's saliva, acting as an electrolyte[2,3]. Corrosion can be defined as a destructive phenomenon of metal or alloy by chemical or electrochemical changes. It takes several forms. First, overall surface attack slowly reduces the thickness or the weight of metal. Second, only isolated area affected produces localized corrosion. Third, corrosion occurs on grain boundaries or other lines of weakness[4]. During orthodontic treatment that may last more

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than 1 year, development of white spot lesions (wsls) is possible unless very good oral hygiene is maintained, to prevent its development, right and careful brushing of teeth with fluoridated dentifrice must be explained to the patients, also, use of mouthwash (fluoridated or herbal), bonding brackets with a glass ionomer cement, topical application of stannous fluoride, and casein phosphopeptide-amorphous calcium phosphate may play a role in reducing the incidence of wsls[4]. However, numerous studies have shown that in an acidic environment and in the presence of fluoride ions (fluoride mouthwashes), the corrosion resistance of certain materials, in particular, titanium, can deteriorate[5].

MATERIALS AND METHODS

A sample of 36 MBT 0.022″ slot stainless steel premolar orthodontic brackets were taken for the study and randomly divided equally into 3 groups (Group 1, Group 2 and Group 3). Once the brackets were assigned to their respective groups, each bracket was numbered 1 to 12 randomly using a liquid-proof marker and then measured for its weight using a digital analytical balance calibrated upto 1/1000 gram and the measurements were duly noted down. After the initial weight measurement was done for every bracket in each of the groups, toothpaste solutions were made. pH of Colgate® Total® 12 Toothpaste in double deionized water was obtained as 7.38, determined using digital ph meter 335. Toothpaste solution for group 1 was prepared by mixing Colgate® Total® 12 Toothpaste and artificial saliva at a 1:4 (w/v) ratio[6], that is 25gm of toothpaste was mixed with 100ml of artificial saliva. The required amount of toothpaste was obtained by weighing it on the digital analytical balance and artificial saliva was measured using a measuring jar calibrated to 100ml. Measured toothpaste and artificial saliva were then transferred to a jar and mixed with a stirrer until a homogenous solution was seen. The ph of this solution was obtained as 7.40. The brackets assigned to group 1 were immersed in the prepared toothpaste solution. pH of Close Up Deep Action Toothpaste in double deionized water was obtained as 6.70, determined using digital ph meter 335. Toothpaste solution for group 2 was prepared by mixing Close Up Deep Action Toothpaste and artificial saliva at a 1:4 (w/v) ratio[6]. Same procedure was followed to get the required amount of toothpaste and artificial saliva as used for Colgate® Total® 12 Toothpaste. Measured toothpaste and artificial saliva were then transferred to a jar and mixed with a stirrer until a homogenous solution was seen. The pH of this solution was obtained as 6.72. The brackets assigned to group 2 were immersed in the prepared toothpaste solution. pH of GC Tooth Mousse in double deionized water was obtained as 7.0, determined using digital ph meter 335. Toothpaste solution for group 3 was prepared by mixing GC Tooth Mousse and artificial saliva at a 1:1.14 (w/v) ratio[6], that is 87.72gm of GC Tooth Mousse was mixed with 100ml of artificial saliva. Same procedure was followed to get the required amount of GC Tooth Mousse and artificial saliva as used for Colgate® Total® 12 Toothpaste. Measured GC Tooth Mousse and artificial saliva were then transferred to a jar and mixed with a stirrer until a homogenous solution was seen. The pH of this solution was obtained as 7.0. The brackets assigned to group 3 were immersed in the prepared solution. All the brackets were immersed in their respective toothpaste solution for 48 hours [simulating the total recommended tooth – brushing time (2 min, twice a day for 2 years) i.e., duration of average orthodontic treatment]. After the completion of immersion time, the brackets were taken from the toothpaste solutions and rinsed with distilled water and air dried using three way syringe. All the brackets were weighed again individually after the immersion in test solutions on a digital analytical balance and the measurements were duly noted with respect to each group.

RESULTS

The one-way ANOVA descriptive statistics for pre - treatment weight of brackets showed that the mean value for group 1, 2 and 3 was, the highest being 0.063308gm [SD = 0.0024307gm], the least being 0.061433gm [SD = 0.0022480gm] and 0.062025gm [SD = 0.0026931gm] respectively (Table 1).

The pre-treatment weights among the samples in group 1 varied from 0.0577 to 0.0656gm. Among the samples in group 2 it varies from 0.0580 to 0.0646gm. Among the samples in group 3 it varies from 0.0574 to 0.0656gm (Table 1).

One-way ANOVA for post – treatment mean value for group 1, 2 and 3 was, the highest being 0.062100gm [SD = 0.0025958gm], the least being 0.059992gm [SD = 0.0021335gm] and 0.060550gm [SD = 0.0036475gm] respectively (Table 2).

The post-treatment weights among the samples in group 1 varied from 0.0570 to 0.0651gm. Among samples in group 2 it varies from 0.0572 to 0.0636gm. Among samples in group 3 it varies from 0.0536 to 0.0652gm (Table 2).

The test of significance for overall comparison in paired sample t-test showed p<0.05 indicating statistically significant pre and post-treatment values (Table 3 and 4).

Table 1 One-way ANOVA - Pre treatment

	Pre treatment (weight in gms)					
	Mean	Minimum	Maximum	Standard Deviation	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Colgate® Total®12 Toothpaste	.0633	.0577	.0656	.0024	.061764	.064853
Close Up Deep Action Toothpaste	.0614	.0580	.0646	.0022	.060005	.062862
GC Tooth Mousse	.0620	.0574	.0656	.0027	.060314	.063736

Table 2 One-way ANOVA -Post treatment

Group	Post treatment (weight in gms)					
	Mean	Minimum	Maximum	Standard Deviation	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Colgate® Total® 12 Toothpaste	.0621	.0570	.0651	.0026	.060451	.063749
Close Up Deep Action Toothpaste	.0600	.0572	.0636	.0021	.058636	.061347
GC Tooth Mousse	.0606	.0536	.0652	.0036	.058232	.062868

Table 3 Paired Sample T test showed significant p value <0.05 for pre treatment Paired Samples Test

	Paired Differences					t	df	P value
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre treatment (weight in gms)	.0013750	.0008683	.0001447	.0010812	.0016688	9.501	35	<0.05

Table 4 Paired Sample T test showed significant p value <0.05 for post treatment Paired Samples Test

	Paired Differences					t	df	P value
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Post treatment (weight in gms)	1.9391194	.8287253	.1381209	1.6587191	2.2195198	14.039	35	.000

DISCUSSION

Metallic appliances are an integral part of orthodontic treatment. Brackets are exposed to the oral cavity, which is a potentially hostile environment where electrochemical phenomena can occur[5], resulting in dissolution or formation of chemical compounds.

Metallic corrosion in the mouth almost never causes the massive destruction found in such situations as the rusting of cars, bridges and chemical plants[1].

In the oral environment, fluoride ions from the fluoride-containing commercial mouthwashes, toothpastes, and prophylactic gels are widely used to prevent dental caries or relieve dental sensitivity or for proper cleaning, are very aggressive on the protective TiO_2 film formed on Ti and Ti alloys, leading to attacked corrosion morphology, decreased polarization resistance and an increased anodic current density or metal ion release[7]. Topical high fluoride concentrations will stay in place and attack the archwire/bracket interface depending on the fluoride concentration. There is also evidence to suggest that some mouth rinses may also increase ionic release from silver soldered joints in orthodontic appliances[2]. In the human mouth, the amount of metal released is affected by (a) salivary constituents which differ according to human health and day times, and (b) different food stuffs and beverages of low pH. During the past 40 years, the prophylactic application, at regular time intervals, of gels and solutions containing high concentrations of fluorides has indeed become more frequent, reaching noticeable impact on the dental caries prevention. The approved dental gels which are generally used constitute fluoridated and acidic preparations, with pH in the range of about 3.2 and 7.7. In the acid and fluoridated environment produced by the Fluogel medium, the protecting oxide film was degraded, leading to a fast corrosion process of the metal. The observation of the electrode surface, under the microscope confirms this result, since the titanium shows a completely rough surface due to the formation of crevices resulting from the metal dissolution, revealing that, in this fluoridated and acidic environment, titanium is undergoing an electrochemical corrosion, which gradually worsens the structure of the metal[9,10]. Even if the oxide film is broken by the presence of a little fluoride, it is suggested that the film immediately regenerates under the open air environment at which the dissolved-oxygen is sufficient, and that the corrosion resistance is maintained. In contrast, under the low dissolved-oxygen concentration conditions, it will take more time or will not be able to regenerate the broken oxide film. A decrease in the dissolved-oxygen concentration tended to reduce the corrosion resistance of Ti and Ti alloys but did not cause a severe corrosion of Ti[11].

When producing stainless steel, the more chromium, nickel and molybdenum incorporated into the alloy, and the less sulphur and carbon, the better the corrosion resistance of the final product. Both the TiN-plated brackets and the non TiN-plated brackets were found to release metal ions into artificial saliva solution, suggesting that, under such conditions, both brackets initially suffer some degree of corrosion[12].

Corrosion was found to be an important factor for the integrity of steel, and pitting became evident after a few days of salt spray exposure and progressively more severe as the corrosion level increased. As the steel surface became rougher, cavities and notches were formed, which made the steel surface locally of smaller diameter than the average value. A considerable reduction in the fatigue limit took place because the mass loss[13] led to a reduction of the exterior hard layer of martensite and a drastic drop in the energy density of the corroded specimens, thus developing stress concentration points that are highly localized at imperfections and especially in the pits and notches of the rib bases of the corroded steel. Wires may remain in the oral cavity for 6 months or more while exposed to topical fluoride, fluoridated water, and toothpaste, and fluoride releasing bracket bonding materials[14]. Likewise brackets, therefore were used in this study.

As deionized water/distilled water is highly pure, does not contain any ions (as they have been removed), has low levels of conductivity, is non-corrosive and will not react with metals[15], it was used to clean all the brackets in all the 3 groups after immersion in respective toothpaste solutions, before weighing them on Digital Analytical Balance.

As in any invitro investigation, the protocol can not exactly simulate clinical conditions[14].

The results obtained indicate that the weight loss in Group 2 [Close Up Deep Action Toothpaste] is the highest followed by Group 3 [GC Tooth Mousse], and the least in Group 1 [Colgate Total 12 Toothpaste] suggesting that the corrosion of the brackets in Group 2 was the highest, followed by Group 3, the least in Group 1. This can be attributed to the pH of the toothpastes and the prepared toothpaste solutions. As the pH of Close Up Deep Action Toothpaste was not available from the Safety Data Sheet, the pH of all the 3 toothpastes in double deionized water – to know the pH of the toothpastes, and prepared toothpaste solutions were determined using Digital pH Meter 335 in the Department of Biochemistry, Navodaya Medical College and Hospital, Raichur. The pH of toothpastes in double deionized water was obtained as 7.38 for Group 1, 6.70 for Group 2 and 7.0 for Group 3. The pH of prepared toothpaste solutions was obtained as 7.40 for Group 1, 6.72 for Group 2 and 7.0 for Group 3. In the acid and fluoridated environment produced by the Fluogel medium, the protective oxide film was degraded, leading to a fast corrosion process of the metal[9]. This explains corrosion based on pH, in turn explains why corrosion of brackets in Group 2 was the highest, as they were immersed in a solution which had an acidic pH, corrosion of brackets in Group 3 was lesser than Group 2 as the pH of solution in Group 3 was neutral, corrosion of brackets in Group 1 was the least as the pH of solution was basic.

CONCLUSION

Toothpastes are the most commonly used oral hygiene aids. As brackets will be in close association with the toothpastes more than other components, it can lead to corrosion as saliva acts as an electrolyte.

The following conclusions can be made from this study,

1. The corrosion of brackets (weight loss) in Group 2 (Close Up Deep Action toothpaste) was the highest owing to the acidic pH of the toothpaste that is, 6.70 in double deionized water and 6.72 when mixed with artificial saliva to make the test solution.
2. The corrosion of brackets (weight loss) in Group 1 (Colgate® Total® 12 toothpaste) was the least owing to the basic pH of the toothpaste that is, 7.38 in double deionized water and 7.40 when mixed with artificial saliva to make the test solution.
3. The corrosion of brackets (weight loss) in Group 3 (GC Tooth Mousse) was between Group 1 and Group 2 owing to the neutral pH of the toothpaste that is, 7.0 in double deionized water and 7.0 when mixed with artificial saliva to make the test solution.

Toothpastes in the present study were used in static equilibrium unlike the dynamic state present in oral cavity, so corrosion may or may not be in the range obtained in this study, also the state of saliva and teeth brushing that removes the oxide layer may have an effect[5]. The brackets used in this study were not subjected to any electrochemical analysis to assess the type of ions lost with the loss in the weight of the brackets, further future research can be undertaken in this aspect. These are the shortcomings of this study.

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