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Effects of Air Abrasive Polishing on Iron Ion Release from Different Metal Self-Ligating Orthodontic Brackets

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ABSTRACT

Introduction: *Treatment with fixed orthodontic appliances compromises the oral hygiene and increases the risk of plaque-related disorders and dental staining in addition to corrosion and corrosion byproduct: ions. The aim of this study was the assessment of the effects of air polishing on Iron ion (Fe) release from stainless steel self-ligating brackets.* ***Materials and methods:*** *A total of 160 self-ligating stainless-steel brackets of 4 brands Damon® Q™ (Damon® Q™, Ormco, Orange, CA, USA), Discovery® SL 2.0 (Dentaraum, Ispringen, Germany), Leone® F1000 (SLB; F1000, Leone SpA, Sesto Florentino, Florentino, Italy) and Lotus Plus® (Lotus plus, Orthotechnology co., Brazil) were exposed to different time of air abrasion polishing (0, 5, 10, 20 seconds) and then immersed in artificial saliva with pH value 6.75 and was incubated at 37°C for 28 days. Fe ion release was assessed using atomic absorption spectrophotometer at 7 days, 14 days and 28 days and the accumulative effect were calculated. Scanning electron microscope (SEM) was used to assess the surface changes and microtopography after polishing for the randomly selected sample. Analysis of variance test (ANOVA) and Tukey's (HSD) test was used to identify the significant difference among the studied groups where the level of significance was set at* $p \leq 0.05$*.* ***Results:*** *The results revealed that all brands showed a significant increase in Fe ion release concomitant with an increase in the polishing time. Damon® Q™ show the least amount of Fe ion release.* ***Conclusion:*** *The air polishing procedure enhanced the amount of Fe ion release to a subtoxic level and could be used in adult patients using 5 sec recommended time of polishing with prolonged intervals between the visits.*

Keywords: Orthodontic appliances, Damon® Q™, Absorption spectrophotometer, Professional dental prophylaxis

INTRODUCTION

Orthodontic treatment with fixed or removable appliance has been increasingly demanded. During orthodontic treatment, however, several drawbacks can be encountered such as plaque-related diseases and allergy. The hostile oral environment may provide a favorable medium for electrochemical corrosion of metallic embedded structures and metal ions release. This is especially true for the brackets, archwires, and auxiliaries that are made of metallic substances [1].

Moreover, the exposure of metal orthodontic components to damaging physical and chemical agents may increase their metallic corrosion [2].

Corrosion and release of corrosion byproducts (ions) of metallic alloys used in the construction of orthodontic bracket have been intensively investigated with regards to its carcinogenic potential, mutagenic and allergenic effects of ions that are released as a result of the corrosion process. Several studies have demonstrated that the major corrosion products are nickel (Ni), iron (Fe) and chromium (Cr) and manganese for stainless steel and titanium alloys, and nickel from nickel-titanium alloy [1,3-6].

On the other hand, fixed braces are considered as a burden to effective cleaning procedure and enhance plaque accumulation and dental staining [7]. The effectiveness of air-polishing system that releases controlled jets of air, water, and utilized different type of airborne abrasive particles such as sodium bicarbonate, calcium sodium phosphosilicate, or calcium carbonate has shown to be more effective than the traditional Professional dental prophylaxis (PDP) for removing the dental plaque; additionally, it promotes less working time and operator effort. Furthermore, this system has been widely used to remove teeth discoloration during orthodontic treatment which compromises adult patients; thus, enhance good patient compliance and satisfaction towards the treatment [8,9].

Limited information in the literature was available about the effects of air polishing procedure on Fe ion release from orthodontic brackets.

PATIENTS AND METHODS

Four brands of stainless steel passive type of self-ligating metal brackets Damon® Q™ (Damon® Q™, Ormco, Orange, CA, USA), Discovery® SL 2.0 (Dentaraum, Ispringen, Germany), Leone® F1000 (SLB; F1000, Leone SpA, Sesto Florentino, Florentino, Italy) and Lotus Plus® (Lotus plus, Orthotechnology co., Brazil) were used. The brackets of each brand were divided into 4 groups of 10 brackets for each group according to different polishing times of 5 seconds, 10 seconds and 20 seconds, and a control group without polishing. For air polishing, Prophy-Mate neo polishing system (Prophy-Mate neo, NSK Co., Japan) was used with Prophy-Mate neo flash pearl calcium carbonate airborne particles (NSK). A purposely made holding device for air polishing was constructed in such a way that the brackets were attached to the plastic base using a double adhesive tape (Figure 1). Then, the airflow handpiece was installed so that its tip is perpendicular to the bracket at a distance of 5 mm using a standardized measuring tool (Figure 1) [10].

After air abrasion procedure, brackets were removed carefully from the metal double adhesive tape using bracket clamping tweezers (Dentaraum, Ispringen, Germany) and immersed in an ultrasonic machine (Codyson, CD-4820, China) for 5 seconds with ethanol to remove the calcium carbonate particles [11]. The bracket was then placed in a vacuum glass tube containing 10 ml of artificial saliva with pH 6.75 in such a way that the brackets were fully immersed in the saliva. Each container secured was closed and placed in the incubator (Fisher Scientific, Pittsburg, PA, USA) at 37°C for 28 days [12]. After 7 days brackets were transferred to another tube containing 10 ml of artificial saliva then after second 7 days bracket were transferred to another tube containing 10 ml of artificial saliva for the remaining period of the study (ISO/IEC 17025:2005).

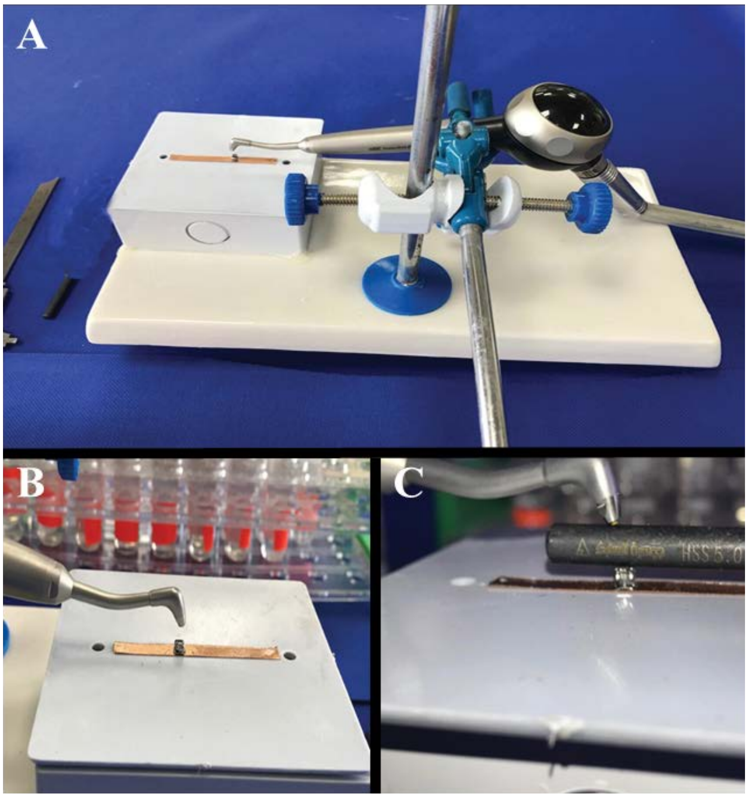

Figure 1 Customized holding device used for air polishing, A: device assembly; B: fixing bracket on a table of the holding device using a double adhesive metal tape; C: distance adjustment

The Fe ion release concentration was assessed using an atomic absorption spectrophotometer (Analytik Jena, Jena, Germany) at 7 days, 14 days, 28 days and the accumulative concentrations were calculated. The surface micromorphology of the brackets as received and after air polishing was evaluated using SEM (Vega-Tescan, Czech Republic) on the randomly selected sample.

RESULTS

The results showed that there was a highly significant increase in the amount of Fe ion release concomitant with an increase in the polishing time throughout the study period. Damon® Q™ showed the least amount of release compared to other brands (Tables 1and 2, and Figure 2). Surface micromorphology of the brackets was evaluated before and after application of calcium carbonate air abrasive polishing visualized at 2000X magnification using SEM. It was found that the use of air-abrasive polishing exaggerates surface changes the tested brackets. This was represented by the appearance of numerous pits with different depth and sizes concomitant with the increase in the polishing time (Figure 3).

Table 1 Accumulative Fe ion release from different self-ligating brackets brands at the different polishing time

Time of polishing	Company	Mean (µg/dl)	S.D.	Min.	Max.	F-test	p-value
Control	Damon® Q™	275.385	1.05822	273.150	276.960	140.354	0.000
	Discovery® SL	301.060	8.26942	290.260	318.040		
	Leone® F1000	311.957	0.67109	311.000	312.840		
	Lotus Plus®	304.219	1.30074	302.460	306.170		
5 sec	Damon® Q™	279.945	0.92254	278.420	280.900	574.223	0.000
	Discovery® SL	330.314	4.0209	325.160	337.230		
	Leone® F1000	319.289	1.90949	315.570	322.620		
	Lotus Plus®	312.373	3.46472	306.640	317.860		
10 sec	Damon® Q™	278.229	28.2186	198.000	289.320	37.754	0.000
	Discovery® SL	341.572	2.91363	337.510	344.730		
	Leone® F1000	329.296	2.24186	326.750	334.040		
	Lotus Plus®	324.391	2.08326	319.820	326.680		
20 sec	Damon® Q™	292.697	0.99327	290.710	293.610	397.414	0.000
	Discovery® SL	353.218	7.31625	347.000	371.820		
	Leone® F1000	343.771	2.36221	339.620	347.990		
	Lotus Plus®	339.951	3.68555	334.490	348.040		

Table 2 Comparison between the mean values of Fe ions released for all different brackets brands at the different polishing time

Time of abrasion (Sec.)	Brands		Mean difference	p-value
control	Damon® Q™	Discovery® SL	-25.67500*	0.000
		Leone® F1000	-36.57200*	0.000
		Lotus Plus®	-28.83400*	0.000
	Discovery® SL	Leone® F1000	-10.89700*	0.000
		Lotus Plus®	-3.15900	0.354
	Leone® F1000	Lotus Plus®	7.73800*	0.001

5 sec.	Damon® Q™	Discovery® SL	-50.36900*	0.000
		Leone® F1000	-39.34400*	0.000
		Lotus Plus®	-32.42800*	0.000
	Discovery® SL	Leone® F1000	11.02500*	0.000
		Lotus Plus®	17.94100*	0.000
	Leone® F1000	Lotus Plus®	6.91600*	0.000
10 sec.	Damon® Q™	Discovery® SL	-63.34300*	0.000
		Leone® F1000	-51.06700*	0.000
		Lotus Plus®	-46.16200*	0.000
	Discovery® SL	Leone® F1000	12.27600	0.236
		Lotus Plus®	17.18100	0.050
	Leone® F1000	Lotus Plus®	4.90500	0.868
20 sec.	Damon® Q™	Discovery® SL	-60.52100*	0.000
		Leone® F1000	-51.07400*	0.000
		Lotus Plus®	-47.25400*	0.000
	Discovery® SL	Leone® F1000	9.447000*	0.000
		Lotus Plus®	13.26700*	0.000
	Leone® F1000	Lotus Plus®	3.82000	0.211
*The mean difference is significant at the 0.05 level				

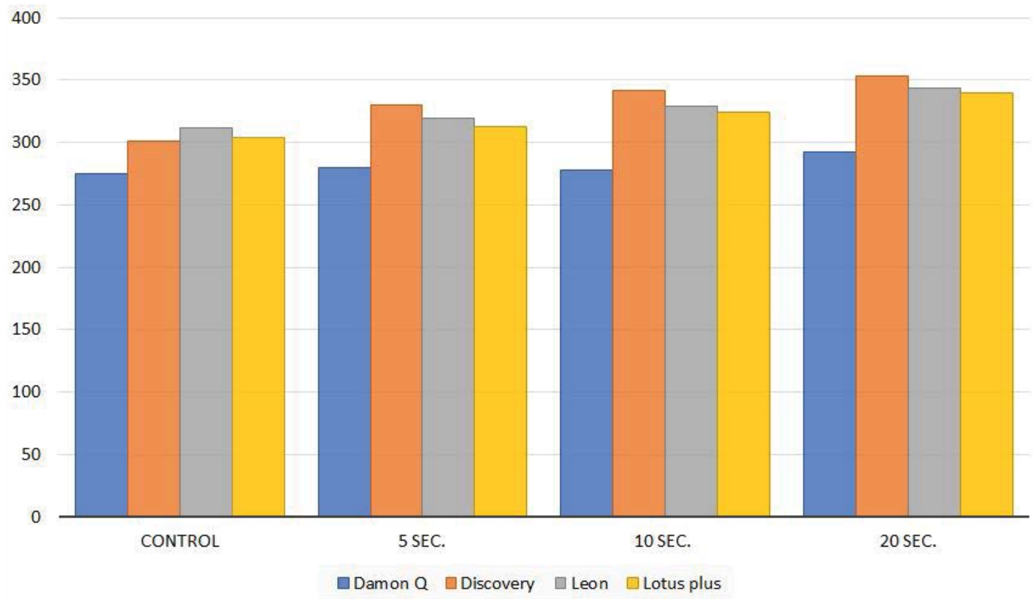

Figure 2 Histogram represents the effect of polishing time on the accumulative Ni ion release of different brackets brands

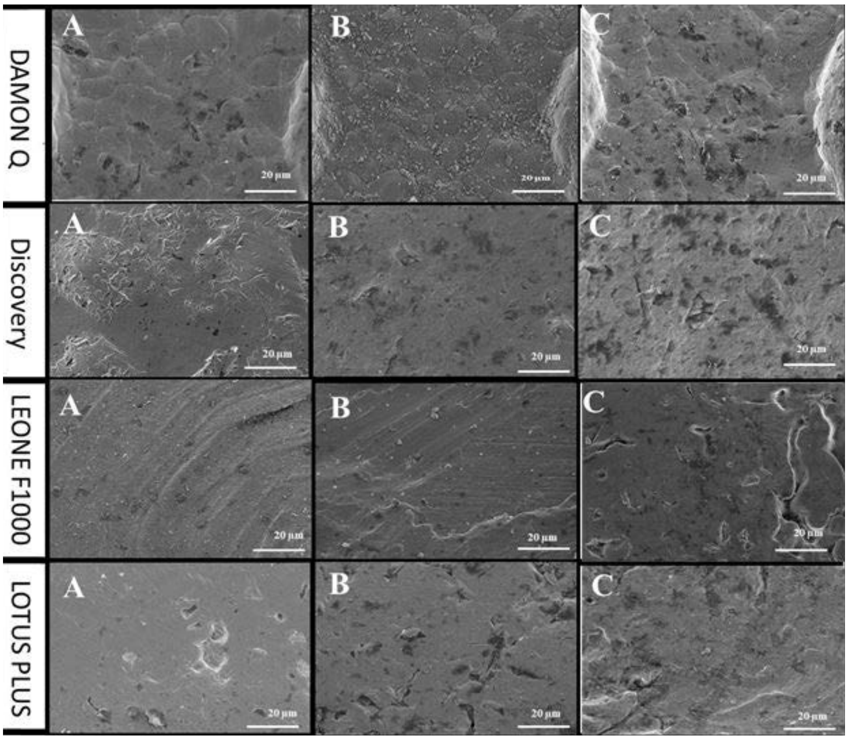

Figure 3 Surface micromorphology of each brand bracket at 2000X magnification using SEM. A: represent the surface of control bracket to air polishing; B: represent the surface of the bracket after 5 sec of air polishing; C: represent the surface of the bracket after 20 sec of air polishing

DISCUSSION

Nowadays, the number of an adult seeking orthodontic treatment is increasing. The dietary habits for the category of those patients differed from adolescents, in that it contains more coloring beverages i.e. coffee and tea, which results in stain deposit on the enamel that requires polishing procedure [13]. Professional dental prophylaxis (PDP), over the years, has traditionally involved the use of a rubber cup or brush and abrasive paste for polishing. This procedure enables the removal of supragingival plaque and stain. However, the use of rubber cup and abrasive paste is often laborious, time-consuming, and ineffective in removing supragingival deposits and stain around bonded orthodontic appliances [14]. So, it was suggested that air flow polishing has an advantage over the traditional PDP ineffectiveness of removing the dental plaque and stain because it promotes less working time and operator effort. Furthermore, this system has been widely used to remove teeth discoloration during orthodontic treatment which compromises adult patients, thus, enhance good patient compliance and satisfaction towards the treatment [8,9].

However, the stainless-steel brackets have lower surface hardness compared to enamel, thus, affected by the air polishing to the best of the author's knowledge. The release of stainless steel self-ligating bracket Fe ion after air polishing was not investigated before. This study demonstrated and emphasized the effect of air polishing on the Fe ion release in artificial saliva with 3 different times of air polishing using calcium carbonate powder [15-17].

Previous studies of ion release suggested that the corrosion process and metal ion release was extended over a period of 4 weeks. So, the incubation period of the brackets in the artificial saliva in this study was set to the period of the 28^{th} day [18,19].

This study examines the Fe ion release because it is the main component in stainless steel alloy used in the manufacturing of stainless steel bracket [20-22].

The increase in the amount of Fe ion released that are in concomitant with an increase in the polishing time could be due to an increase in the surface roughness of the brackets that resulted in an increase in the surface area of the bracket. It was suggested that the longer the polishing time the greater the roughness texture and increase in the total surface area [11].

Additionally, the increase in the surface roughness resulted in an increase in the surface area of contact with the saliva causing an increase in the amount of Fe ion release [23]. These surface irregularities enhance the corrosion process by their adverse effects on the protective layer as proposed by Pakshir, et al., in 2011 and Roberge, in 2012 who claimed that when there are manufacturers pits the passive layer is dissolved locally and the depth of the pit is increased rapidly in the underlying metal [24,25]. An electrochemical cell is developed, in which the anode is an extremely small area of active metal and the cathode is a large area of passive metal; hence, more ions were elaborated and detected [24,25].

Moreover, it was reported that the corrosion resistance property is the result of the protection conferred by a chromium-rich passive layer, which is typically on the order of 3 to 5 nm thick, or about 15 layers of atoms [26]. The passive layer is formed by an oxidation-reduction reaction in which the chromium and iron are oxidized, and the passivating agent is reduced. If this layer is not allowed to form, or if the layer is broken, rapid general and/or galvanic corrosion can follow [26]. Indeed, the abrasive particles of the polishing procedure had an undesirable effect on the protective passive layer, chromium oxide layer, which was, probably, removed and exposed a fresh metal to corrode and thereby accelerated the surface damage [27,28].

Results from the current study found that the total amount of ion release after using the professional cleaning by air polishing measure was below the average daily intake which is far from toxic levels (the tolerable upper intake level for nickel is 45 mg/day for an adult) [29,30]. This conclusion comes in accordance with Natarajan, et al., in 2011 who reported that systemic toxic effect that is from fixed orthodontic appliances is highly unlikely, but it may cause a delayed allergic reaction [31].

CONCLUSION

Calcium carbonate air polishing could be used during orthodontic treatment considering the recommended polishing time i.e. 5 seconds, with prolonged polishing intervals in adult patients. Additionally, although all brackets brands displayed a subtoxic level of the tested ions, Damon® Q™ brackets showed the lowest level of Fe compared to others and can be recommended.

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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