MDJ

Effects of air abrasive polishing on chromium ion release from different metal self-ligating orthodontic brackets

Dr. Husam Majid Hameed. Master Student .*
Dr. Dheaa Hussein Al-Groosh. Assistant Professor .*

Abstract

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 aims this study was assessment the effects of air polishing on Chromium ion (Cr) release from stainless steel self-ligating brackets.

one hundred and sixty self-ligating stainless-steel brackets of four 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) then immersed in artificial saliva with pH value 6.75 and incubated at 37°C for 28 days. Cr ion release was assessed using atomic absorption spectrophotometer at 7, 14 and 28 days and accumulative effect was calculated. Scanning electron microscope (SEM) were used to assess the surface changes and microtopography after polishing for randomly selected sample. Analysis of variance test (ANOVA), and Tukey's (HSD) test were used to identify the significant difference among the studied groups where the level of significance set as $P \leq 0.05$.

The results revealed that all brands showed significant increase in Cr ion release concomitant with an increase in the polishing time. Damon® Q™ show the greatest amount of Cr ion release

Conclusion: The air polishing procedure enhanced the amount of Cr 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.

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

* Department of Orthodontics, College of Dentistry, University of Baghdad.

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 has been intensively investigated with regards to its carcinogenic potential, mutagenic and allergenic effects of ions that 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 air borne 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 toward treatment [(8, 9)].

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

Materials 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 four groups of 10 brackets for each group according to different polishing times of 5, 10 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 way that the brackets were attached to the plastic base using a double adhesive tape **Figure (1 B)**. Then, the airflow hand piece was installed so that its tip is perpendicular to the bracket at a distance of 5mm using a standardized measuring tool **Figure (1 C)** [(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 five seconds with ethanol to remove the calcium carbonate particles [(11)]. Bracket then placed in a vacuum glass tube containing 10ml of artificial saliva with pH 6.75 in such a way that the brackets were fully immersed in the saliva. Each container secured closed and placed in the incubator (Fisher scientific, Pittsburg, PA, USA) at 37°C for 28 days [(12)]. After seven days brackets were transferred to another tube containing 10ml of artificial saliva then after second seven days bracket are transferred to another tube contain 10ml of artificial saliva for the rest period of study **(ISO/IEC**

17025:2005).

The Cr ion release concentration was assessed using atomic absorption spectrophotometer (Analytik jena, Jena, Germany) at 7, 14, 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 randomly selected sample.

Results

The results showed that there was a highly significant increase in the amount of Cr ion release concomitant with an increase in the polishing time though out the study period. Damon Q showed the greatest amount of release compared to other brands **Tables (1 and 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 of the tested brackets. This was represented by the appearance of numerous pits with different depth and sizes concomitant with the increase in polishing time **Figure (3)**.

Discussion

During recently, the number of 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 in effectiveness 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 toward 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 authors knowledge, Cr ion release of stainless steel self-ligating bracket after air polishing was not investigated before. This study demonstrated and emphasized the effect of air polishing on the Cr ion release in artificial saliva with three different time of air polishing using calcium carbonate powder. [15-17]**.**

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

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

The increase in the amount Cr ion release that are in concomitant with increase in the polishing time this 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 surface roughness resulted in an increase in surface area of contact with the saliva causing increase in the amount of Cr ion release [23].

These surface irregularities enhance the corrosion process by their adverse effects on the protective layer as proposed by **Pakshir et al., (2011)** [24] **and Roberge (2012)** [25] who claimed that when there are manufacturers pits the passive layer dissolved locally and the pits depth increase rapidly in the underlying metal. An electrochemical cell developed where its anode is 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 [27], which was, probably, removed and exposing a fresh metal to corrodes and thereby accelerating surface damage [28].

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, Damon Q brackets showed the greatest level of Cr ion release compared to others and can be recommended.

References

1- Kuhta M, Pavlin D, Slaj M, Varga S, Lapter-Varga M, Slaj M. Type of archwire and level of acidity: effects on the release of metal ions from orthodontic appliances. The Angle Orthodontist. 2009;79(1):102-10.
2- Patel R, Bhanat S, Patel D, Shah B. Corrosion Inhibitory Ability of Ocimum Sanctum Linn (Tulsi) Rinse on ion release from orthodontic brackets in some mouthwashes: An invitro study. Natl J Community Med. 2014;5(1):135-9.
3- Veien NK, Borchorst E, Mattel T, Laurberg G. Stomatitis or systemically ‐ induced contact dermatitis from metal wire in orthodontic materials. Contact dermatitis. 1994;30(4):210-3.
4- Ramadan AA-F. Effect of nickel and chromium on gingival tissues during orthodontic treatment: a longitudinal study. World journal of orthodontics. 2004;5(3).
5- Schultz J, Connelly E, Glesne L, Warshaw E. Cutaneous and oral eruption from oral exposure to nickel in dental braces. Dermatitis: contact, atopic, occupational, drug. 2004;15(3):154-7.
6- Menezes LM, Quintão CA, Bolognese AM. Urinary excretion levels of nickel in orthodontic patients. American Journal of Orthodontics and Dentofacial Orthopedics. 2007;131(5):635-8.
7- Gorelick L, Geiger AM, Gwinnett AJ. Incidence of white spot formation after bonding and banding. American Journal of Orthodontics. 1982;81(2):93-8.
8- Hosoya Y, Johnston J. Evaluation of various cleaning and polishing methods on primary enamel. The Journal of pedodontics. 1989;13(3):253-69.
9- Darby M, Walsh M. Management of extrinsic and intrinsic stains. Dental

Hygiene Theory and Practice. 2010:511-28.
10- Barnes CM. Air polishing: a mainstay for dental hygiene. 2013.
11- Parmagnani EA, Basting RT. Effect of sodium bicarbonate air abrasive polishing on attrition and surface micromorphology of ceramic and stainless steel brackets. The Angle orthodontist. 2011;82(2):351-62.
12- Chaturvedi T, Upadhayay S. An overview of orthodontic material degradation in oral cavity. Indian Journal of Dental Research. 2010;21(2):275.
13- Joiner A. Tooth colour: a review of the literature. Journal of dentistry. 2004;32:3-12.
14- Barnes CM, Russell CM, Gerbo LR, Wells BR, Barnes DW. Effects of an air-powder polishing system on orthodontically bracketed and banded teeth. American Journal of Orthodontics and Dentofacial Orthopedics. 1990;97(1):74-81.
15- Craig R, Peyton F. The microhardness of enamel and dentin. Journal of Dental Research. 1958;37(4):661-8.
16- Tsujikawa M, Noguchi S, Yamauchi N, Ueda N, Sone T. Effect of molybdenum on hardness of low-temperature plasma carburized austenitic stainless steel. Surface and Coatings Technology. 2007;201(9-11):5102-7.
17- Tantbirojn D, Huang A, Ericson M, Poolthong S. Change in surface hardness of enamel by a cola drink and a CPP–ACP paste. Journal of dentistry. 2008;36(1):74-9.
18- Gürsoy S, Acar AG, Şeşen Ç. Comparison of metal release from new and recycled bracket-archwire combinations. The Angle Orthodontist. 2005;75(1):92-4.
19- Dos Santos AAR, Pithon MM, Carlo FGC, Carlo HL, de Lima BASG, dos Passos TA, et al. Effect of time and pH on physical-chemical properties of orthodontic brackets and wires. The Angle Orthodontist. 2014;85(2):298-304.
20- Cunat P-J. Alloying elements in stainless steel and other chromium-containing alloys. ICDA, Paris. 2004.
21- Eliades T, Zinelis S, Bourauel C, Eliades G. Manufacturing of orthodontic brackets: A review of metallurgical perspectives and applications. Recent Patents on Materials Science. 2008;1(2):135-9.
22- David E.J. Talbot JDRT. Corrosion Science and Technology. 3rd Edition ed. Boca Raton2018.
23- Fontana MG. Corrosion engineering: Tata McGraw-Hill Education; 2005.
24- Pakshir M, Bagheri T, Kazemi M. In vitro evaluation of the electrochemical behaviour of stainless steel and Ni-Ti orthodontic archwires at different temperatures. The European Journal of Orthodontics. 2011;35(4):407-13.
25- Roberge PR. Handbook of Corrosion Engineering. 2nd ed. ed. New York: McGraw Hill Inc; 2012.
26- Kerber SJ, Tverberg J. STEEL Surface. ADVANCED MATERIALS & PROCESSES. 2000:33.
27- Marcus P. Corrosion mechanisms in theory and practice: Crc Press; 2011.
28- Uhlig HH. Uhlig's corrosion handbook: John Wiley & Sons; 2011.

Table 1: Accumulative Cr ion release from different self-ligating brackets brands at different polishing time

p-value	F-test	Max.	Min.	S.D.	Mean (µg/dl)	company	time of polishing
0.000	826.555	0.01	0.01	0.001	0.0132	Damon Q	control
		0	0	0.0004	0.0019	Discovery	
		0	0	0.0003	0.0026	Leon	
		0	0	0.0006	0.0025	Lotus plus	
0.000	94.146	0.02	0.02	0.0007	0.0177	Damon Q	5 sec.
		0.01	0.01	0.0015	0.0082	Discovery	
		0.01	0.01	0.0018	0.0082	Leon	
		0.01	0.01	0.0016	0.0107	Lotus plus	
0.000	92.773	0.03	0.02	0.0015	0.0253	Damon Q	10 sec.
		0.02	0.01	0.0014	0.0153	Discovery	
		0.02	0.01	0.0014	0.0167	Leon	
		0.02	0.02	0.0015	0.0188	Lotus plus	
0.000	30.598	0.04	0.03	0.0028	0.0316	Damon Q	20 sec.
		0.03	0.02	0.0014	0.0242	Discovery	
		0.03	0.03	0.0012	0.027	Leon	
		0.04	0.03	0.0028	0.0322	Lotus plus	

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

p-value	Mean difference	Brands		Time of abrasion (Sec.)
0.000	.01126*	Discovery	Damon Q	control
0.000	.01061*	Leone		
0.000	.01072*	Lotus Plus		
0.089	-0.00065	Leone	Discovery	
0.2	-0.00054	Lotus Plus		
0.976	0.00011	Lotus Plus	Leone	
0.000	.00949*	Discovery	Damon Q	5 sec.
0.000	.00948*	Leone		
0.000	.00699*	Lotus Plus		
1	-0.00001	Leone	Discovery	
0.003	-.00250*	Lotus Plus		
0.003	-.00249*	Lotus Plus	Leone	
0.311	.01001*	Discovery	Damon Q	10 sec.
0.000	.00855*	Leone		
0.000	.00645*	Lotus Plus		
0.128	-0.00146	Leone	Discovery	
0.013	-.00356*	Lotus Plus		
0.014	-.00209*	Lotus Plus	Leone	
0.000	.00738*	Discovery	Damon Q	20 sec.
0.000	.00463*	Leone		
0.935	-0.00057	Lotus Plus		
0.037	-.00275*	Leone	Discovery	
0.000	-.00795*	Lotus Plus		
0.000	-.00520*	Lotus Plus	Leone	

* The mean difference is significant at the 0.05 level

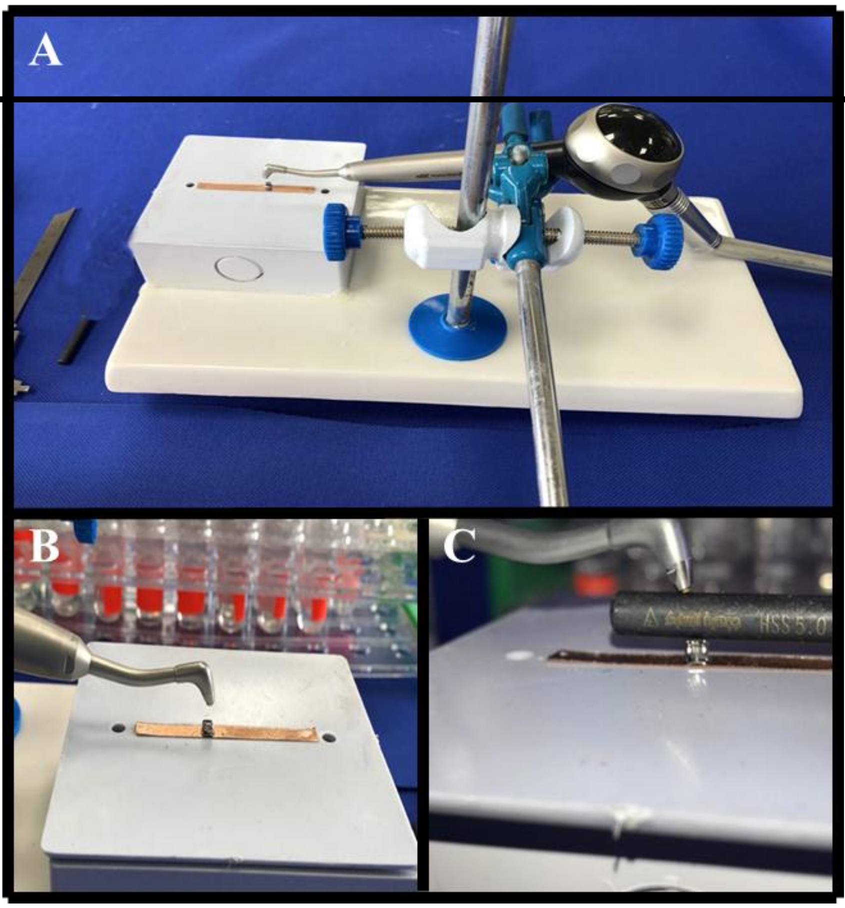

Figure 1: Customized holding device used for air polishing A) device assembly; B) Fixing bracket on a table of the holding device using a double adhesive metal tape; C) Distance adjustment.

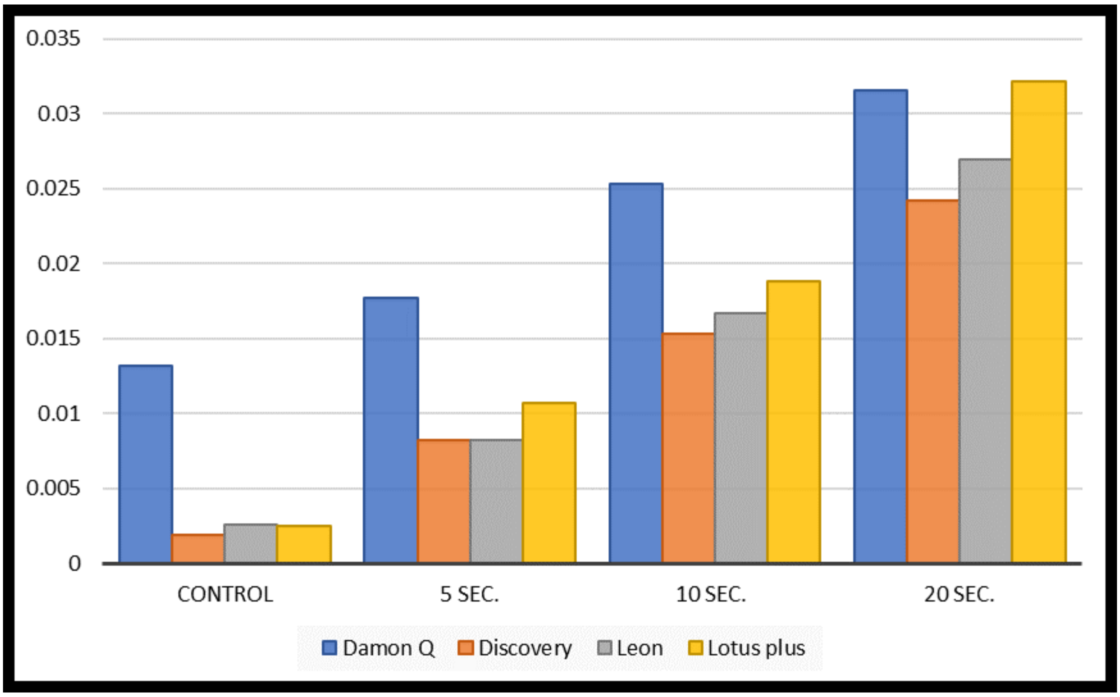

Figure 2: Histogram represent the effect of polishing time on the accumulative Cr ion release of different brackets brands.

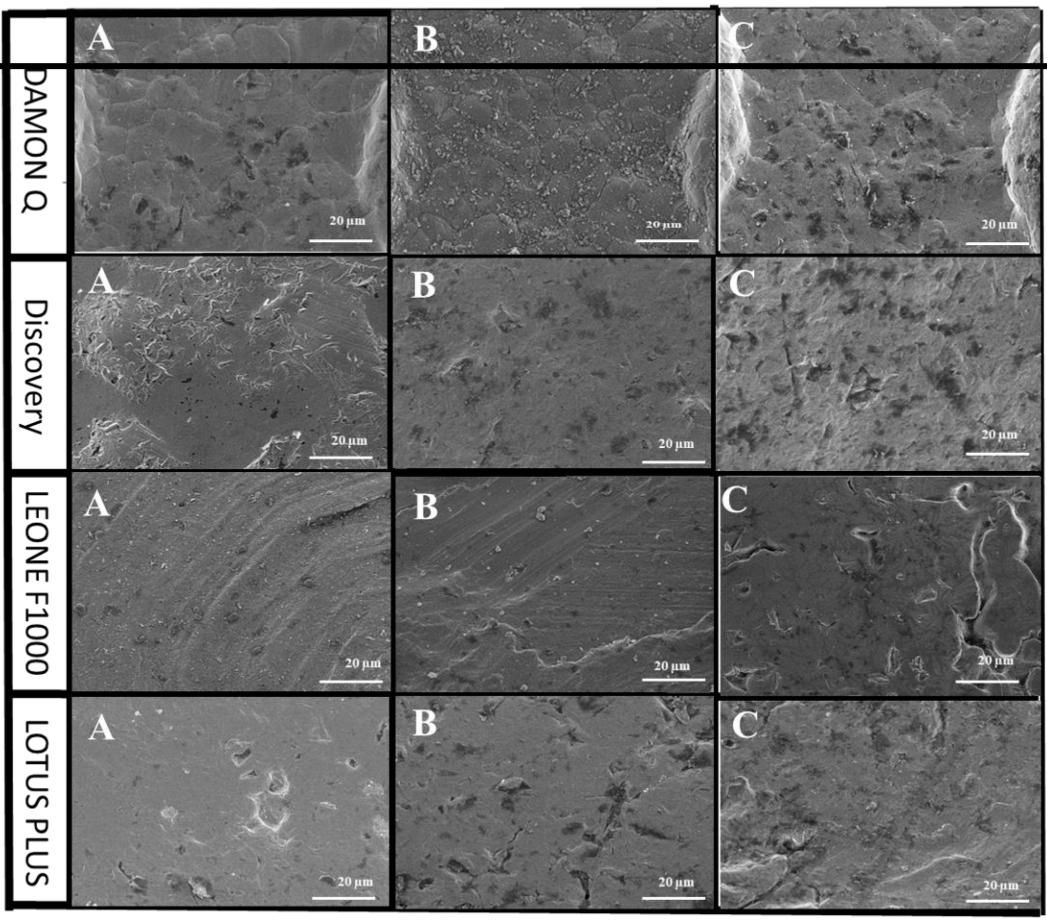

Figure 3: Surface micromorphology of each brand bracket at 2000X magnification using SEM. A) represent the surface of control bracket to air polishing; B) represent the surface of the bracket after 5sec. of air polishing; C) represent the surface of bracket after 20sec. of air polishing;