Strength of composite repair using different diamond burs grits for roughening: immediate and 6-month findings

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Running title: Composite repair using diamond burs

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Abstract:

Objective: To evaluate the effects of surface treatment and intermediate agent hydrophilicity on durability of the composite repair by means of the repair strength, silver nitrate uptake, surface roughness measurement and scanning electron microscopy analysis (SEM).

Methods: Fifty composite resin blocks with 12 mm of diameter and 4 mm high (Opallis, FGM) were polished and, after 7 days, ~~were~~ divided into 5 groups: no treatment (NT); roughening with a fine-grit (FDB); medium-grit (MDB); coarse-grit diamond burs (CDB) and 50-μm aluminum oxide sandblasting (AO). A hydrophobic (Adhesive bottle, Scotchbond Multi-Purpose [SBMP]) or hydrophilic adhesive (Adper Single Bond 2 [SB]) was then applied. The same composite was used for repair. Composite-composite bonded sticks (0.9mm2) were tested immediately [IM] or after 6 months [6M] of (submersed?) water storage in tension (1.0mm/min). Two bonded sticks from each tooth were immersed in a 50% solution of silver nitrate, photo-developed and analyzed by SEM. Composite specimens after surface treatments were analyzed with a contact profilometer (Ra) and SEM. The data was statistically analyzed by ANOVA and Tukey´s post hoc tests.

Results: For both adhesives, no significant difference was detected among the IM and 6M repair strength. The AO has shown~~ed~~ the highest composite repair strength in both adhesives system (MPa), while the NT group has presented~~showed~~ the lowest. The different diamond burs had an intermediate performance in terms of repair strength. Early signs of degradation after 6M were detected by silver nitrate uptake only for the SB adhesive. The ranking of surface

roughness values (Ra) from the lowest to the highest level wasere as the followings: NT < FDB < MDB < AO ≤ CDB.

Conclusions: The aluminum oxide treatment provides the highest composite repair strength, regardless of the hydrophilicity of the intermediate agent and storage period. Early signs of degradation were detected for SB after 6 months as silver nitrate deposits within the adhesive layer.

Clinical Relevance statement:

Keywords:

Introduction

When a composite restoration fails as a result of discoloration, microleakage, ditching at the margins, delamination or simply fracture, the restoration needs to be repaired or replaced (Mjor et al 1993, Denehy et al 1998, Mjor et al 2002, Gordan et al 2006, Ozcan et al 2006). The total replacement of the restoration is the most common procedure experienced in daily clinical practice (Mjor et al 2002), however, when large portions of the restorations are completely removed, significant loss of ~~sound~~ dental tissues occurs (Krejci et al. 1995; Moscovich et al. 1998; Gordan et al. 2002) because is often difficult to remove a tooth-colored adhesive restoration without removing an integral part of the tooth. As ~~a~~ consequence, the dental structure is weakened and pulp injury may occur. In this context, composite repair is considered a minimally invasive protocol with the additional advantages that it is a low cost ~~less costly~~ alternative and demands less chair-side time (Mjor et al 1993, Blum et al 2003).

A previous study had demonstrated that the interfacial bonding between layers of composites decreases as the original layer sets (Boyer et al 1984), as well ~~as~~ after prolonged water storage (Tezvergil et al 2003, Brendeke e Ozcan 2007) or others aging methods (Tezvergil et al 2003, Brendeke e Ozcan 2007, Ozcan et al 2007, Papacchini et al 2007, Passos et al 2007, Ozcan t al 2010). Thus, ~~in an~~ attempts to improve the bonding between the existing composite restorations and the repairing composite~~,~~ using different surface treatments have been suggested. Among them, air abrasion with aluminum oxide (Swift et al 1992, Turner et al 1993, Swift et al 1994, Kupiec et al 1996, Brosch et al 1997, Shahdad e Kennedy 1998, Yap et

al 1998, Yap et al 1999, Lucena Martins et al 2001, Oztas et al 2003, Bonstein et al 2005, Cavalcanti et al 2007, Papacchini et al 2007a, Papacchini et al. 2007c, Passos et al 2007, Dall'Oca et al 2008, Souza et al 2008, Rathke et al 2009, Yesilyurtet al. 2009, Costa et al 2010, Loomans et al 2011(dent mat)), chemical treatments with phosphoric acid (Lucena Martins et al 2001, Shen et al 2004, Bonstein et al 2005, Cavalcanti et al 2007, Oscan et al 2007, Papacchini et al 2007a, Dall'Oca et al 2008, Fawsy et al 2008, Rathke et al 2009, Yesilyurt et al 2009, Loomans et al 2011, Loomans et al 2011), hydrofluoridric acid (Swift et al 1992, Swift et al 1994, Brosch et al 1997, Lucena Martins et al 2001, Trajtenberg et al 2004, Passos et al 2007, Papacchini et al 2007a, Souza et al 2008, Yesilyurt et al 2009, Loomans et al 2011, Loomans et al 2011), silane application (Swift et al 1994, Bonstein et al 2005, Brendeke e Ozcan 2007, Oscan et al 2007, Papacchini et al 2007c, Papacchini et al 2007d, Passos et al 2007, Fawsy et al 2008, Rathke et al 2009, Rinastiti et al 2010,) and surface roughening with diamond burs (Bonstein et al 2005, Cavalcanti et al 2007, Papacchini et al 2007a, Dall'Oca et al 2008, Rathke et al 2009, Yesilyurt et al 2009, Costa et al 2010, Loomans et al 2011(dent mat)) are used to optimize the adherence of repair material to the existing composite restoration. In regard to the latter, fine (Papacchini et al 2007a, Costa et al 2010), medium (Dall'Oca et al 2008, Rathke et al 2009) and coarse (Bonstein et al 2005, Cavalcanti et al 2007, Yesilyurt et al 2009, Loomans et al 2011 (dent mat)) diamond burs grits have been employed by the authors with no consensus ~~i~~on which one is the better alternative.

It is worth mentioning that not only ~~does~~ the surface treatment plays a role in composite repair strength. In order to guarantee an

intimate adaptation of the repair material to polished composite, an intermediate material is required, as the repairing composite does not properly wet the treated resin composite (nonsense statement!) (Boyer et al 1984, Brosch et al 1997, Yap et al 1998, Rathke et al 2009)7,16,26,34. Hydrophilicity of the intermediate material for bonding may impair durability of the interfacial bond repair, since more hydrophilic adhesives tend to absorb more water over time (Malacarne et al 2006)40; however, few attempts have been made to address this issue (Papacchini et al 2007)11.

Based on that, the aim of this study was to evaluate the effects of surface treatment, with different diamond bur grits and intermediate materials, on the immediate and long-term ~~and~~ durability ~~results~~ of the composite repair of recently polished restorations by means of the repair strength and silver nitrate uptake (SNU) tests. Additionally, the effects of the different treatments on the composite roughness and micromorphological features will be investigated. The null hypothesis investigated is that there is no difference in terms of composite repair strength, and nanoleakage will be observed in all~~between the~~ different combinations of surface treatment and intermediate material tested.

Materials and Methods

Fifty resin composite blocks were made by layering 2 mm thick increments of a microhybrid resin composite (Opallis, FGM Dental Products, Joinville, SC, Brazil, shade A3) in a addition silicone mold (4 mm high and with a diameter of 12 mm). Each increment was condensed with a clean plastic filling instrument to avoid contamination and light-cured for 40 seconds (VIP, BISCO Inc, Schaumburg, IL, USA, output: 600 mW/cm2). The last increment was covered and compressed with a glass microscope slide in order to obtain a flat surface. Each specimen was removed from the mold and the surfaces of the composite blocks were polished with Sof-Lex Pop On disks (3M ESPE, St. Paul, MN, USA). Each one of the four disks was used for 10 s in the surface with constant and intermittent pressure and after then stored in a dark vial with water at 37°C for one week.

The specimens were then randomly divided into 5 groups according to the kind of surface treatment applied: Group NT: no further treatment was performed in the composite surface; Group DBF: roughening with a fine-grit diamond bur for 10 s under water cooling (#2135F, KG Sorensen, São Paulo, SP, Brazil, 46 μm mean particle size); Group DBM: roughening with a medium-grit diamond bur for 10 s under water cooling (#2135, KG Sorensen, São Paulo, SP, Brazil, 91 μm mean particle size); Group DBC: roughening with a coarse-grit diamond bur for 10 s under water cooling (#2135G, KG Sorensen, São Paulo, SP, Brazil, 151 μm mean particle size) Group AO: the surfaces were sandblasted with 50 μm aluminum oxide powder for 10 seconds at a working distance of 5 mm at a pressure of 5.5·Pascals (Pa) with an intraoral sandblaster (Microetcher II, Danville Engineering Inc, San Ramon, CA, USA).

~~For~~ A cleaning ~~purposes of cleaning, a~~ 35% phosphoric acid etchant (Scotchbond etchant gel, 3M ESPE, St Paul, MN, USA) was applied for 30 seconds. After water-rinsing (30 s) and air-drying (10 s), specimens of each group were randomly assigned to two sub-groups according to the intermediate agents investigated: hydrophobic, non-solvated bonding group ([SBMP] Adhesive bottle, Adper Scotchbond Multi Purpose Plus, 3M ESPE, St. Paul, MN, USA) and the hydrophilic and solvated adhesive group ([SB] Adper Single Bond 2, 3M ESPE, St. Paul, MN, USA). Both adhesives were rubbed in the composite surfaces for 10 s. Solvent evaporation was performed using an air-spray for 10 s at a distance of 5 cm, in the groups bonded with Adper Single Bond 2. The same procedure was performed in the specimens from SBMP group just for standardization purposes. The adhesive layer was light-cured for 10 s using the same light curing unit for the composite resin blocks. The intermediate agents used in the study, and their chemical composition are reported in Table 1.

Two 2-mm increments were then placed over the treated surfaces with the same composite resin and they were light-cured with the same light-curing device for 40 s. Bonded composite-composite samples were sectioned with a slow-speed diamond saw (Isomet; Buehler, Lake Bluff, IL, USA) under water cooling in both “x” and “y” directions across the bonded interface to obtain bonded sticks with a cross-sectional area of approximately 0.9 mm2. The bonded sticks from each composite-composite block were then divided to be tested either immediately [IM] or after 6 months [6M] of water storage at 37°C.

Microtensile testing

The actual cross-sectional area of each stick was measured with the digital caliper to the nearest 0.01 mm and recorded for subsequent calculation of the repair bond strength (Absolute Digimatic, Mitutoyo, Tokyo, Japan). Each bonded stick was attached to a jig in the universal testing machine (Kratos Dinamometros, São Paulo, SP, Brazil) with cyanoacrylate resin (Super Bonder gel, Loctite, São Paulo, SP, Brazil) and subjected to a tensile force at 1.0 mm/min. The failure modes were evaluated at 400X (HMV-2, Shimadzu, Tokyo, Japan) and classified as cohesive (failure exclusively within the composite~~, -~~ C)~~,~~ or adhesive (failure at composite-composite interface – A), or adhesive/mixed (failure at composite-composite interface that included cohesive failure of the neighboring composite~~,-~~ A/M).

After analyzing the microtensile bond strength data for normalizationty (?) of data distribution (Kolmogorov–Smirnov test) and homogeneity of variances (Levene's test), a two-way repeated measures analysis of variance (ANOVA) was applied for each adhesive system, considering ~~with~~ the composite repair strength as ~~the~~ dependent variable and surface treatment and storage time (IM vs. 6M) as ~~the~~ independent factors. The storage period was considered the repeated measure (???). The Tukey's test was used for post-hoc comparisons at a significance level of 0.05.

Silver Nitrate uptake (SNU)

Two bonded sticks from each composite block at each storage period were not tested in tension but coated with two layers of nail varnish applied up to within 1 mm of the bonded interfaces. The specimens were re-hydrated in distilled water for 10 min prior to immersion in an aqueous solution of 50%wt of silver nitrate for 24 h. Conventional silver nitrate was prepared according to the protocol

previously described by Tay et al 2002. The sticks were placed in the conventional silver nitrate in darkness for 24 h, rinsed thoroughly in distilled water and immersed in a photo-developing solution for 8 h under a fluorescent light to reduce silver ions into metallic silver grains within voids along the bonded interface.

Specimens were wet polished using SiC paper with decreasing grit (1000, 1200, 1500, 2000, 2400) and 1 and 1/4 µm diamond paste (Buehler Ltd, Lake Bluff, IL, USA) using a polish cloth. They were ultrasonically cleaned, air dried, mounted on aluminum stubs and sputtered with carbon (MED 010, Balzers Union, Balzers, Liechtenstein). Composite-composite interfaces were analyzed in a scanning electron microscope (JSM 6060, JEOL, Tokyo, Japan) operated in the backscattered electron model. The working distance was 8 mm and the accelerating voltage was 20 KV.

Three pictures were taken of each specimen and they were all taken by a technician who was blinded to the experimental conditions under evaluation. The images were ~~only~~ qualitatively and quantitatively analyzed.

Surface roughness measurement

Thirty resin composite blocks were made by a microhybrid resin composite (Opallis, FGM Dental Products, Joinville, SC, Brazil, shade A3) in an addition silicone mold (3 mm high and with a diameter of 7 mm). Each increment (± 1mm thickness) was condensed with a clean plastic filling instrument to avoid contamination and light-cured for 40 seconds (VIP, BISCO Inc, Schaumburg, IL, USA, output: 600 mW/cm2). The last increment was covered and compressed with a glass microscope slide in order to obtain a flat surface. ~~.~~ Each specimen was removed from the mold and the surfaces of the composite blocks

were polished with Sof-Lex Pop On disks (3M ESPE, St. Paul, MN, USA). Each one of the four disks was used for 10 s in the surface with constant and intermittent pressure and after then stored in a dark vial with water at 37°C for one week.

The specimens were then divided to each the different surface treatment groups and treated as mentioned (n= 6 per group). Surface roughness test was performed with a contact profilometer (Mitutoyo Surftest 301, Mitutoyo, Tokyo, Japan). Five successive measurements in different directions were recorded for all specimens in each group, and the average surface roughness (Ra) value thereof obtained. The cut-off value for surface roughness was 0.25 mm, and the sampling length for each measurement was 1.25 mm. Data were analyzed using one-way ANOVA and Tukey's test at a significance level of 0.05.

Scanning electron microscopy analysis

The same specimens used in the roughness test were prepared for scanning electron microscopy (JSM 6400, JEOL, Tokyo, Japan) analysis. Specimens were sputter-coated with gold to a thickness of approximately 200Å in a vacuum evaporator. Photographs of representative areas of the polished and treated surfaces were taken at ×1200 magnification. The images were treated using Image J® software to extract the gray level Z for each pixel located at position (X,Y), and exported as (X,Y,Z) profiles which were analyzed using the software Qtiplot® in order to calculate the total roughness and estimate the total surface area. The roughness in gray level is compared to the (Ra, Rs, Rt) experimental values in order to calibrate the gray level in milimeters. Due the self-similar features observed in the AO specimen, a technique based on fractal geometry was applied to estimate the actual surface area with more accuracy. The results

for the global roughness and estimated surface area of the samples are shown in Table 4. In Figure 4 the three stages of the image treatment are exemplified for a DBC sample. The sketch of the technique used to estimate the surface area is also shown.

Resultss

Microtensile Testing

Mean values and standard deviations (MPa) of composite repair strength for each adhesive are shown in Table 2. The two-way repeated measures analysis of variance (ANOVA) for SBMP showed that onlyjust the surface treatment wais significant (p<0.0001). The highest composite repair strength (MPa) was observed for the aluminum oxide group. All the diamond bur groups haved an intermediate performance between the aluminum oxide and control groups. The lowest composite strength repair was observed for the control group.

Similarly, the two-way repeated measures analysis of variance (ANOVA) for SB showsed that only the surface treatment was significant (p < 0.0001). The highest composite repair strength (MPa) was observed for the groups aluminum oxide group– coarse and medium diamond bur group. The lowest composite strength repair was observed for the diamond fine bur group and for the control group.

Silver Nitrate Uptake

Representative images of the SB and SBMP adhesives can be seen in Figures 1 and 2, respectively. The type of surface treatment did not interfere with the silver nitrate deposition. No silver nitrate deposition was seen for both adhesives in the immediate period. However, after six months of water storage, spotted silver nitrate deposits became evident for the SB groups. This finding was not observed for the SBMP adhesive.

Surface Roughness Test and SEM Analysis

Means and standard deviations (µm) of the roughening produced by the different surface treatments are shown in Table 3. One-way ANOVA showed that surface roughness was statistically significant ($p<0.0001$). The ranking of surface roughness values (Ra) from the lowest to the highest level was the followingwere as follows: control group < fine diamond bur group < medium diamond bur group < aluminum oxide group < coarse diamond bur group.

The lowest surface roughness values (Rz/Rt) were observed in control group, followed by the fine diamond bur group. The medium diamond bur group had an intermediate performance. The highest roughness values were observed in aluminum oxide group and in coarse diamond bur group. The SEM images of the roughness produced by the different treatments are shown in Figure 3. One can observe that the pattern of roughness produced by the diamond burs and the aluminum oxide groups were quite different. The peaks and valleys produced by the diamond burs are mainly unidirectional and with similar dimensions, while aluminum oxide produced a more three dimensional roughness with variations in the peaks and valleys heights, exhibiting self-similar fractal features.

Discussion

The results of this study indicate ~~showed~~ that any kind of roughening produced either by aluminum oxide ~~and~~ or diamond bur can increase the repair bond strength, when compared to the control group with no treatment. T~~ and t~~his finding is in agreement with other studies (Turner et al 1993, Kupiec et al 1996, Brosch et al 1997, Shahdad et al 1998, Lucena-Martín et al 2001, Oztas et al 2003, Papacchini et al 2007, Souza et al 2008, Costa et al 2010). This has an important clinical implication. If repair is to be performed on a recently polished composite surface, clinicians should attempt to increase the surface area prior to the procedure.

However, the present investigation demonstrated that variations in the diamond bur grits did not affect the repair bond strength. Although the coarse burs produced higher roughness than did the fine and medium burs, the pattern of micro-retentions produced by the burs were quite similar. Ermis et al, (2008) investigating the effect of different burs on the bond strength of self-etch adhesives to dentin also reached similar conclusions, i.e., the diamond bur grits did not seem to have an important effect on adhesion to dentin.

Microretentive interlocking has been reported to be the most important factor for establishing a bond between old and repair composites and most likely dominates chemical bonds to the resin matrix or to exposed filler particles (Brosch et al 1997, Shahdad et al 1998). In fact, it is confirmed by the lack of improvements in terms of repair strength when silane is applied to aged composite, with the aim to improve chemical bond with the repair composite (Matinlinna et al

2004, Bonstein et al 2005)~~,~~ ~~is~~ a further evidence that micromechanical interlocking may be the main bonding mechanism underlying composite repair.

However~~,~~ it is worth mentioning that the increase in roughness does not necessary means increasinged surface area for adhesion. If we compare the roughness produced by the aluminum oxide and coarse diamond bur one can note that they are similar, but the resulting roughness pattern produced by these two procedures are quite different under SEM evaluation. A more regular pattern of roughness was produced by the coarse diamond bur with unidirectional peaks and valleys, while a more three-dimensional roughness was produced by the aluminum oxide sandblasting with variations in the peaks and valleys heights and self-similar features. SEM images of earlier studies (Lucena-Martín et al 2001, Bonstein et al 2005, Papacchini et al 2007, Dall'oca et al 2008, Rathke et al 2009, Yesilyurt et al 2009, Costa et al 2010)11,14,15,18,22,26,32 agree with the present investigation, demonstrating that aluminum oxide sandblasting is able to produce more micro-retentive features. The image treatment indicates ~~One may speculate~~ that the available area for adhesion ~~area~~ produced by aluminum oxide isseems ~~to be~~ much higher than that produced by the coarse diamond bur, despite the similar Ra roughness produced by both clinical approaches. Besides ~~that~~, one cannot rule out ~~the fact~~ that a smear layer is produced when the composite is roughened with a diamond bur, finding not observed in the aluminum oxide-treated surfaces (???). Whether this has an important effect on the differences observed is yet to be investigated.

Previous studies demonstrated that the use of an adhesive after mechanical roughening has a significant effect on the repair bond

strength (Shahdad et al 1998, Lucena-Martín et al 2001, Tezvergil et al 2003, Oztas et al 2003) and this may be attributed to the adhesives seeping into and leveling off the micro-relief produced by mechanical roughening. But there is a lack of information in literature ~~lacks information about~~ concerning the influence of hydrophilicity of the intermediate agent on the durability of the composite repair. The results of the current study is in agreement with an earlier study (Costa et al 2010)14 that demonstrated that hydrophilicity of the intermediate agent did not affect the immediate and 6-month composite repair strength.

However, spotted silver nitrate deposits were seen in specimens bonded with the solvated, hydrophilic system (SB) after six months of water storage. Probably, t~~T~~his ~~likely~~ resulted from the increased water sorption and solubility of the hydrophilic adhesive layer (Malacarne et al 2006, Malacarne-Zanon 2009). Although this finding did not result in any reduction in composite repair strength, it represents early signs of degradation. This may lead to marginal discoloration of the repaired interface over time and eventually interfacial debonding over the long run. Perhaps if the evaluation of ~~such~~ the composite repair was~~ere~~ done ~~under~~ after more prolonged periods of time, reductions in the repair strength with SB could have been detected. The specimens were only stored for six months~~,~~ because this is the storage period mostly used by researchers to study degradation of resin dentin bonds (Gwinnett et al 1995, Stanislawczuk et al 2009, Reis et al 2010)41-43.

The extent to which the results of the current investigation may be extrapolated for the clinical scenario and how it may affect clinical longevity of a clinical repair are issues ~~is~~ yet to be addressed.

Conclusions

The aluminum oxide treatment provides the highest composite repair strength, regardless of the hydrophilicity of the intermediate agent and storage period. ~~Have n~~No significant difference in the adhesion was observed among~~between~~ the diamonds groups. Early signs of degradation were detected for SB after 6 months as silver nitrate deposits within the adhesive layer.

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Table 1 – Composition of the materials employed in this study.

Material	Composition
Opallis composite (FGM Dental Products)	Bis-GMA monomers, Bis-EMA, TEGDMA, UDMA, camphorquinone, co-initiator, silanized barium-aluminum silicate glass (particle size of 0.5 µm, 79.8 wt%), pigments and silica.
Adper Single Bond 2 (3M ESPE)	Bis-GMA, HEMA, dimethacrylates, ethanol, water, a novel photoinitiator system and a methacrylate functional copolymer of polyacrylic and polyitaconic acids, silica nanofiller (5nm diameter silica particles, 10 wt%)

Adhesive, Adper Scotchbond Multi Purpose Plus (3M ESPE)	Adhesive bottle: Bis-GMA, HEMA and initiators

Abbreviations: Bis-GMA: bis-phenol A di-Glycidyl Methacrylate; Bis-EMA: bis-phenol A di-Glycidyl Methacrylate ethoxylated; TEGDMA: Triethylene Glycol Ddimethacrylate, UDMA: Urethane Dimethacrylate; HEMA: Hydroxyethyl Metacrylate.

Table 2 – Means and standard deviations (MPa) of composite repair strength for all experimental conditions

TREATMENT	SBMP							
	IMMEDIATE		6 MONTH		IMMEDIATE		6 MONTH	
polished	35,2 ± 6,9	C	32,5 ± 7,3	C	35,7 ± 4,8	c	41,0 ± 5,9	b, c
fine	46,3 ± 5,8	B, C	42,5 ± 7,2	B, C	41,2 ± 2,8	b, c	46,4 ± 3,0	a, b
medium	44,7 ± 6,3	B, C	34,8 ± 2,6	B, C	45,4 ± 5,0	a, b	39,3 ± 6,0	b, c
coarse	47,5 ± 3,8	B	45,2 ± 8,3	B	43,5 ± 3,3	a, b	37,6 ± 3,3	b, c

	,	,	,	,		
	8	9	4	1		
a	5	A 5	A 4	a 5	a	
l	6	2	, 9	, 2		
u	,	,	B ,	b ,		
m	4	1	7	6		
i						
n	±	±	±	±		
u						
m	7	5	4	3		
	,	,	,	,		
o	4	9	9	5		
x						
i						
d						
e						

** Comparisons are valid only within adhesive systems. Means represented by the same upper or lowercase letters indicate statistically similar means*

Table 3 – Means and standard deviations (μm) of the roughening produced by the different surface treatments

Treatment	Ra		Rz		Rt	
polishing	0.17 ± 0.08	A	1.09 ± 0.37	a	2.08 ± 0.94	a
fine	1.49 ± 0.23	B	7.11 ± 1.37	b	10.46 ± 2.67	b
medium	2.31 ± 0.35	C	9.99 ± 1.28	c	13.92 ± 0.97	c
coarse	3.82 ± 0.27	E	16.50 ± 1.50	d	22.22 ± 1.34	d
aluminum oxide	3.34 ± 0.14	D	16.28 ± 0.67	d	21.66 ± 0.72	d

Comparisons are valid each column. Means represented by the same upper or lowercase letters indicate statistically similar means.

Table 3 – Mean height H(μm), Ra(μm) and surface area (mm2) estimated from image analysis of the different treatments

Treatment	H	Ra	Surface area (k=3)	Surface area (k=2)
polishing	0.55	0.19 ± 0.35	-	0.700002(1)*
fine	3.1	1.51 ± 0.27	0.734(2)	0.702(2)
medium	3.91	2.29 ± 0.41	0.776(8)	0.706(7)
coarse	5.37	3.00 ± 0.54	0.724(5)	0.704(4)
Aluminum oxide	5.77	4.14 ± 0.75	1.66(54)	0.97(31)

The values within parenthesis indicates the error in the precedent significant number.

* k=1 approximation was used for polishing sample.

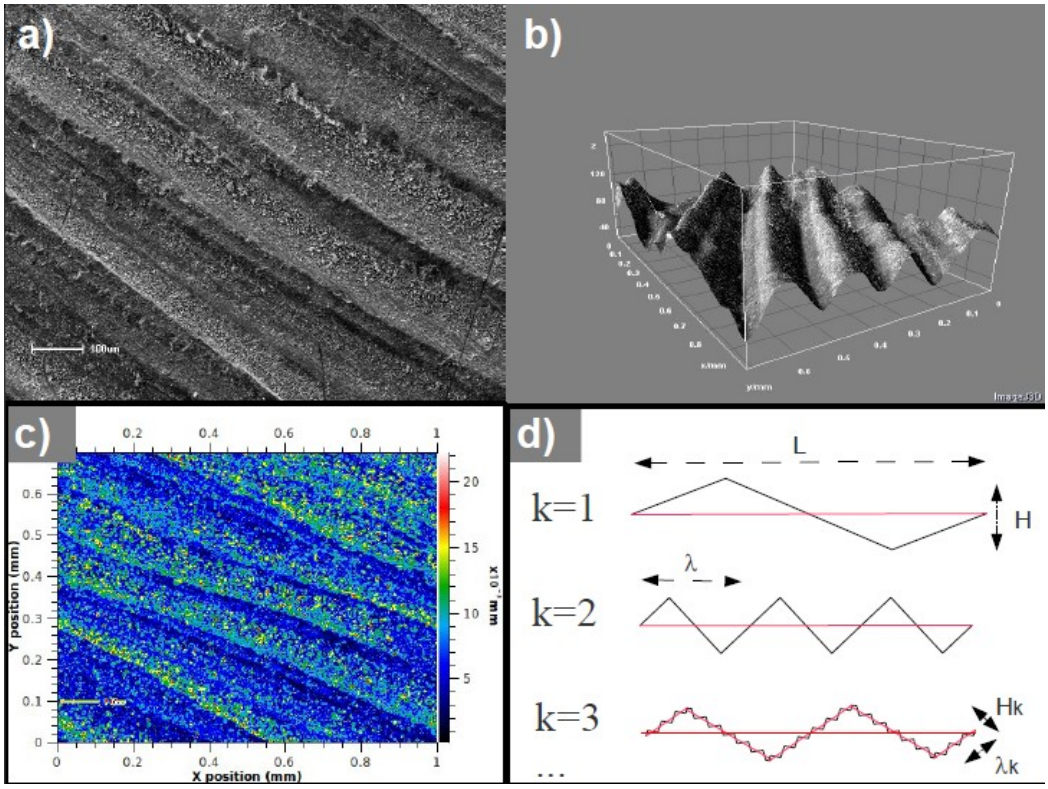

Figure4: a) Photograph of an specimen of DBC group. b) 3D surface plot from Image J software. c) Contour plot made from data extracted from Image J. d) Sketch of the model used to estimate the surface area. The level of self-similarity applied is indicated as k. Note that N λ = L.