The effect of a self-adhesive coating on the load bearing capacity of tooth-colored restorative materials.

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Abstract:

Objectives: To compare the flexural strength and Vickers hardness of tooth-colored restorative materials with and without applying a self-adhesive coating for up to six months.

Methods: Specimens were prepared from three resin composites (RC), two resin-modified glass-ionomer cements (RM-GIC), and two conventional glass-ionomer cements (CGIC). All materials were tested both with and without applying G-Coat Plus (GCP). Specimens were conditioned in 37 °C distilled deionized water for 24 h, 1, 3 and 6 m. The specimens were strength tested using a four-point bend test jig in a universal testing machine. The broken specimen's halves were used for Vickers hardness testing. Representative specimens were examined under an environmental scanning electron microscope.

Results: Data analysis showed that regardless of time and materials, generally the surface coating was associated with a significant increase in the flexural strength of the materials. Applying the GCP decreased the hardness of almost all materials significantly ($p < 0.05$) and effect of time intervals on hardness was material dependent.

Conclusions: The load bearing capacity of the restorative materials was affected by applying self-adhesive coating and aging. The CGICs had significantly higher hardness but lower flexural strength than the RM-GICs and RCs.

Introduction:

Direct tooth-coloured restorations have become the most popular treatment option in clinical dentistry due to decreasing use of dental amalgam and an increased demand for aesthetic restorations. Tooth-colored restorative materials are categorized into two groups, namely resin composites (RC) and glass-ionomer cements (GIC). Continuous development and improvement in the physical and mechanical properties of these materials enhanced their popularity.[1-2] However, investigations of their clinical performance have determined fracture of resin composite restorations as the most prominent cause of failure.[3-4]

One of the recommended options for improving mechanical and physical properties of tooth-coloured restorative materials is using surface protection such as a self-adhesive coating. Infiltration of a self-adhesive coating, e.g. G-Coat Plus (GC Corp, Tokyo, Japan; GCP), is claimed by the manufacturer to give internal protection against crack initiation and fill porosities, both of which may reinforce and strengthen the materials, especially GICs. Its protective effect from extrinsic water may also allow complete maturation of the GIC reaction with delayed water exposure.[5] The self-adhesive coating bonds to GIC and provides a lamination effect that has been reported to increase the fracture toughness and shear punch strength of GICs, but decrease the surface hardness of the material.[6,7]

The effect of storage in water for extended periods of one or more months on aesthetic restorative materials varies. Some studies have shown slight to substantial decreases in the elastic modulus and tensile strength of resin composites.[8-10] While others have reported no change or an increase in flexural strength and fracture toughness after storage in water.[11,12] A material with relatively low mechanical strength has been reported to have high surface hardness and resistance to wear.[13] Therefore; it seems that comparing materials for their flexural strength and surface hardness would have practical relevance, and the correlation between the failure load and failure mode with or without surface coating would be of clinical interest.

Studies exist which evaluate the effect of self-adhesive coating (GCP) on the clinical performance of conventional GIC and the mechanical properties of GIC such as fracture toughness, flexural strength, shear punch strength and hardness,[7] yet little is known about its effect on RM-GIC or resin composite.[6,7,14-20]

Knowledge of the mechanical properties of a material, with regard to its surface protection using a self-adhesive coating agent, can elucidate its behavior and, therefore, determine its clinical uses and performance. Hence, in the present laboratory study the aim was to compare flexural strength and hardness of seven aesthetic restorative materials, asses the effect of storage in distilled deionized water (DDW) for up to six months, and determine the effect of resin surface coating on the mechanical properties of the materials. The null hypothesis was that no difference existed between the materials; that aging and surface coating does not affect flexural strength and Vickers hardness of the materials.

Materials and Methods

Specimen preparation

Seven aesthetic restorative materials (Shade A2) were investigated (Table 1). A custom-made brass and aluminium mould was employed to prepare a total of 40 bar-shaped specimens of 25 mm length, 2 mm height and 5 mm width. The mould was filled with the material and sandwiched between two plastic matrix strips and glass plates in order to extrude excess. The light-curable materials were cured through transparent strips according to the manufacturers' instructions for the recommended exposure time. Each bar-shaped specimen was cured in three equal sections using a light-polymerizing LED unit with a wavelength range of 440-480 nm and output of 1500 mW/cm^2 (Radii plus LED, SDI, Victoria, Australia). Each specimen was removed from the mould and light-cured on the opposite side similarly. One side of the specimen was wet polished manually in a circular motion with a sequence of 600, 1000, 1500 and 2000 grit silicon carbide papers (Norton Tufbak Saint-Gobain Abrasives Pty Ltd, Victoria, Australia) and identified by marking the unpolished side. Each specimen was washed in DDW for 45 s in an ultrasonic bath (L&R 2009 Ultrasonic Cleaning System, NJ, USA) between each grinding. Specimens were divided randomly into two equal groups of 20 specimens and designated as coated and uncoated groups. In the coated group, GCP was applied to the polished surface with brush in a thin layer, and cured using the light-polymerizing unit for 20 s according to the manufacturer’s recommended exposure time. The specimens in the uncoated group were used without further preparation. Both groups subdivided into the four groups of five specimens and stored in distilled water at 37 ^{o}C for 24 h, 1 m, 3 m and 6 m. After each time interval, the specimens were removed, blotted dry with paper towel and tested using a universal testing machine (Model 5544; Instron Corporation, MA, USA).

Flexural Strength testing

Before testing, width and height of each specimen were measured using a digital calliper with accuracy of 0.1 mm (Absolute Caliper, Mitutoyo Asia Pacific Pte. Ltd). The specimens were placed in the universal testing machine using a four-point bend test jig, the polished and coated surface was face down such that maximum tensile stresses were generated on this surface, loaded at a crosshead speed of 0.5 mm/min, and calibrated using the internal calibration. The maximum load at specimen failure was recorded and flexural strength was calculated using the following formula: $\sigma = 3.F.(L_1-L_2) / 2.b.d^2$, where F is the load at the fracture point (N), L_1 and L_2 are the outer and inner roll span respectively, b is specimen width (mm), and d is the specimen height (mm).

Vickers hardness testing

The specimen's halves were used for hardness testing. For each group three specimens were selected and each specimen was subjected to three indentations 35 µm apart across the specimen surface by applying a load of 300 g for 10 s using a Micro-Vickers Hardness Tester (402 MVD, Shanghai Co., Ltd, PRC) (n = 3 half x 3 indentation = 9) and the average was recorded as Vickers Hardness Number (VHN).

SEM Micrograph

To observe the line of fracture, two randomly selected specimens from each group were examined under an environmental scanning electron microscope (ESEM: FEI Quanta, OR, USA) with original magnification range X60 - 1000.

Statistical Analysis

The data were statistically analysed using SPSS software package (version 18, SPSS Inc., IL, USA). For each test, the data set was divided into seven groups, according to the materials used, and separate analyses of variance (ANOVA) were carried out for each material, evaluating the effect of surface coating, and immersion time. Possible differences among time, surface coating and material were explored by a three-way ANOVA. If the differences were not statistically significant at the 5% level, interaction terms were ignored and the main effects of each factor were fitted to each material. Pairwise differences were then assessed using Tukey's test for each material in the terms of any factor (surface coating, and time) found to be significant at the 5% level with respect to other factors.

Results

Flexural strength

The results of three-way ANOVA indicated no significant interaction between combinations of factors ($p = 0.210$); no significant interaction between materials and coating ($p = 0.205$) or coating and time ($p = 0.339$) but there was a statistically significant interaction between time and materials ($p < 0.001$). The effect of time was depending on the materials. Regardless of time and materials, generally the surface coating significantly increased flexural strength of the materials. Overall mean and standard deviation values of flexural strength for the two surface treatments at all immersion times for each material are presented in Table 2.

There were statistically significant differences in flexural strength (MPa) between all materials ($p < 0.05$) except between Fuji IX Fast and Riva Self Cure ($p = 1.00$). Fuji IX Fast (11.5 ± 3.4) and Riva Self Cure (14.7 ± 2.5) showed the lowest and second lowest strength values (MPa) respectively, whilst G-ænial Universal Flo had the highest (107.9 ± 14.4) (Table 2).

Vickers Hardness

There was strong interaction between the combinations of the three factors (three-way ANOVA; $p < 0.001$). Overall mean values of VHN and statistical differences between the two surface treatments at all immersion times for each material are presented in Table 3. Among the uncoated materials, Fuji IX Fast showed the highest initial VHN (76.6 ± 7.3) followed by Luna (64.5 ± 7.3) and Riva self-cure (60.5 ± 7.3), whilst Gradia had the lowest VHN (43.9 ± 4.7). There was a statistically significant difference between hardness of the majority of materials ($p < 0.05$). G-coat plus decreased the VHN of almost all materials significantly ($p < 0.05$) and effect of time interval was material dependent.

SEM findings

The thickness of the GCP layer on the coated specimens and fracture mode of a few coated and uncoated samples are illustrated in Figures 1-3. Localised variation of the surface layer thickness of GCP on the surface of G-ænial Universal Flo is evident (Figure 1). Bubbles are present on the surface of uncoated G-ænial Universal Flo which is the likely site of crack initiation (Figure 2). A uniform layer of GCP is present on the surface of Fuji IX preventing the opening of a crack in the subsurface of the material (Figure 3).

Discussion

Results of the present study showed significant differences in Vickers hardness among the coated and uncoated materials and within each material over storage time. Conventional GICs (Fuji IX Fast and Riva Self Cure) showed significantly greater VHN than RM-GICs (Fuji II LC and Riva Light Cure). This result is in agreement with a previous study which assessed VHN of three conventional GICs: Ketac-Fil, Ketac-Molar and Ketac-Silver (3M ESPE) and three RM-GICs: Photac-Fil, Vitremer (3M ESPE) and Fuji II LC (GC) stored in DDW at 37 °C for 12 months.[21] Significant VHN differences among the materials studied and within each material over storage time were reported. GICs, except for Ketac-Silver, showed a higher VHN throughout the study period. The authors concluded that VHN of both the conventional and RM-GICs experienced variation over time and the addition of resin to the GIC did not improve hardness. Other authors reported lower Knoop hardness and wear resistance for RM-GICs compared to conventional GICs.[13] Higher VHN was reported to be correlated with combination of smaller glass particles and lower porosity in the materials' structure.[13] Type of inorganic filler is another possible factor affecting hardness of the materials.[22] Materials containing barium glass fillers had lower surface hardness than materials containing zirconia/silica filler particles.[22]

Significantly lower VHN was obtained in the present study after applying GCP compared to the uncoated groups in almost all tested materials for all storage time which is in agreement with Bagheri and colleagues study.[7] The hardness of the surface of restorative material is confounded by the presence and variable thickness of the layer of GCP present on its surface (Figure 1). The GCP is generally softer than the subsurface restorative material and it will result in an average hardness value indicative of the presence and thickness of the GCP layer and the depth of penetration of the indenter into the subsurface restorative material.

SEM showed localized variability in the surface layer thickness of the GCP (Figure 1) which would influence the surface hardness and variability in hardness values obtained for each material. Site of crack initiation may be associated with bubbles or voids present on or just below the surface of the restorative material, e.g. uncoated G-ænial Universal Flo (Figure 2). Therefore, coating the cement surface with an unfilled resin may fill surface voids or infiltrate the surface and fill subsurface voids decreasing stress concentration, crack propagation or further initiation and improving flexural strength.

Effect of water storage on the hardness of the materials was greatly dependent on the type of material and surface condition. For instance, hardness of uncoated Fuji II LC and Gradia decreased significantly over the time while Fuji IX Fast and Riva self-cure increased significantly whereas others did not change significantly. This can be due to the susceptibility of the materials for water uptake due to their composition and tendency to absorb water, e.g. presence of hydrophilic resin such as hydroxy-ethylmethacrylate (HEMA) in Fuji II LC.[23] The application of protective resin or varnish over the glass-ionomer surface prevents water loss, resulting in less shrinkage of the material.[24]

In contrast to VHN, flexural strength of the all materials increased after applying GCP. These results are in agreement with the results of other studies.[19, 20] Zoergiebel and Ilie[19] in their study of the effect of coating, aging and storage media on the conventional GIC with new zinc formulation revealed that resin coating led to significant improvements in flexural strength due to absence of visible surface defects like crazing and voids for GIC fillings. They also reported resin coating did not affect microhardness of tested materials after the coating layer was removed. Miyazak et al.[20] reported an increase in flexural strength of the coated GIC after 1 and 24 h of cement mixing. The authors suggested that the surface coating agent might protect the surface during the early stage of setting reaction to withstand stress and increase its mechanical properties.

Bagheri et al.,[6] reported that coating with GCP increased the fracture toughness of conventional GIC significantly whilst it did not affect that of RM-GIC. Other authors also reported significant improvement of fracture resistance, wear resistance and flexural strength of conventional GIC coated before water contamination in comparison with that of uncoated and GIC coated after water contamination.[25,26] Bonifacio and colleagues measured flexural strength of coated and uncoated Fuji IX GP Extra specimens, with the flexural strength of uncoated specimens (20.2 MPa) was significantly lower compared to the coated specimens (34.9 MPa).[26]

In a three year evaluation of the clinical performance of Fuji IX GP Extra, Fuji IX GP Extra with GCP and a hybrid resin composite, the marginal adaptation and wear results in all three groups were determined to be clinically acceptable.[18] At three years, there was still a difference between the wear of Fuji IX GP Extra with and without a GCP coating, but this was not statistically significant. However, the specimens coated by GCP, showed a positive tendency towards wear protection. At three years, the performance of the resin composite restorations was not significantly different from that of the GIC restorations.[18]

The increase in flexural strength of the coated samples in the present study may in part be due to the prevention of opening and the propagation of cracks present on the surface of the restorative material. (Figure 3 coated Fuji IX Fast). Furthermore, conventional GIC (Fuji IX Fast) with the highest VHN, revealed the lowest mean value of flexural strength and Gradia with the lowest VHN showed the highest strength along with G-ænial Universal Flo. Time was a critical factor in the flexural strength of uncoated and coated materials. Flexural strength of almost all GICs showed an increase as time increased up to three months and then decreased after six month. This improvement in the strength up to three months could be related to the acid / base reaction that proceeds slowly until final maturation completion which may take a few months.[5]

A direct relationship between mechanical properties of GICs and microstructure of these materials has been shown.[13] It has been speculated that factors such as the integrity of the interface between the glass particles and the polymer matrix, the particle size, and the number and size of voids have critical influence in controlling the mechanical properties. The more integrated the microstructure, the higher the flexural strength and diametral tensile strength.[13]

Among GICs and resin composites, G-ænial Universal Flo showed the highest flexural strength (107.9 ±14.4 MPa) followed by Gradia direct (79.9 ± 12.1). This performance could be related to the type of resin matrix used in these materials. Polymer matrix e.g. urethane dimethacrylate (UDMA) seems to absorb less water than bisphenol A-glycidyl methacrylate (Bis-GMA). Pearson et al. determined that under normal curing conditions a urethane dimethacrylate material showed lower water sorption than Bis-GMA.[27] It is evident that the water sorption and solubility of resin composites is based on the type of resin matrix used. The water uptake in Bis-GMA-based resins increased from 3 to 6% as the percentage of Triethylene glycol dimethacrylate (TEGDMA) increased from 0 to 1%.[28]

Varying the relative amounts of UDMA, Bis-GMA and TEGDMA has a significant effect on the mechanical properties of the resin composition.[29] The replacement of Bis-GMA or TEGDMA by UDMA results in an increase in tensile and flexural strength, and that replacement of Bis-GMA by TEGDMA reduced flexural strength.[29] The highest flexural strength value was obtained when Bis-GMA was substituted with UDMA and the amount of UDMA increased above 30%.[29] Therefore, the presence UDMA/ TEGDMA in the composition of G-ænial Universal Flo and UDMA in Gradia direct could be responsible for their higher strength in comparison with the other tested materials in the present study. Gradia and G-ænial Universal Flo showed a decrease in strength as time increased with the lowest strength after six-month immersion in water.

Conclusions:

Within the limitations of this study, applying self-adhesive surface coating and aging in water significantly increased the flexural strength of the materials whilst the hardness of almost all materials decreased significantly ($p < 0.05$). Effect of time intervals on hardness was material dependent. Flexural strength of the resin composites was the highest and CGICs the lowest. Conventional GICs showed significantly greater VHN but lower flexural strength than the RM-GICs and resin composites. Considering that the results of the present study are valid for the strict laboratory conditions, laboratory data may provide an insight into clinical performance. Therefore, due to the observation of the microscopic localized variability in surface layer thickness of the GCP, results may be more accurate if clinicians apply more than a single layer of coating on the restorative materials.

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Figure legends:

Figure 1. Localized variation of the surface layer thickness of G coat on the surface of G-ænial Universal Flo (Arrows).

Figure 2. Void (A) present on the surface of uncoated G-ænial Universal Flo is the likely site of crack initiation (B).

Figure 3. Uniform layer of G-coat present on the surface of Fuji IX Fast (Arrows).

Table 1. Material Description.

Name	Manufacture	Material Type	Filler/Resin type, wt / vol%, filler size	Batch #
Fuji II LC	GC Corporation, Tokyo, Japan	RM-GIC	55vol%, AFSG/Poly-HEMA Average 5.9 µm	1405261
Fuji IX Fast	GC Corporation, Tokyo, Japan	CGIC	AFSG (95% wt%)	1405201
Gradia Direct	GC Corporation, Tokyo, Japan	Microhybrid Composite	77wt%, 65vol%, FAS, Silica, prepolimerized filler Average 0.85µm, UDMA, Dimethacrylate	1311063
G-ænial Universal Flo (GæUF)	GC Corporation, Tokyo, Japan	Universal Light-cured Flowable Composite	UDMA, Bis-EMA, TEGDMA, Silicon dioxide 1-5%, SG 69 wt%, 50 vol%	1402252
Riva Light Cure	SDI, Vic, Australia	RM-GIC	53vol%, Powder:FSG,Silica, Liquid:PA,TA,HEMA, Average size 6.5 µm	K 1402032 EG
Riva Self Cure	SDI, Vic, Australia	CGIC	50 vol% Powder: PAAFASG Liquid: PAA, TA, Average size 6 µm	C 1403121EG
Luna	SDI, Vic, Australia	Nanohybrid Composite	SAS, AS (0.04 - 3 µm, Average 1.0 µm), (80 wt%, 61 vol%), UDMA/ Bis-EMA/ TEGDMA,	2096SN

G-Coat Plus	GC corporation, Tokyo, Japan	Nanofilled self-adhesive light- cure	MMA 40-50wt%, Urethane MA 30-40wt% Silicon Dioxide 10-15 wt%	1311121

PAAFASG=Polyacrylic acid Fluoro-aluminosilicate glass, PAA=Polyacrylic acid, TA=Tartaric acid AFSG= Aluminium-fluoro-silicate glass, SG=Strontium glass, SAS= Strontium alumino silicate, AS= amorphous silica, FSG= fluoroalumino silicate glass, PA=Polyacrylic acid, TA=Tartaric acid, HEMA= Hydroxyethylmethacrylate, RM-GIC= Resin modified glass ionomer cement, CGIC=Conventional glass ionomer cement, MMA= Methyl methacrylate, MA= Methacrylate, TEGDMA= Triethylene glycol dimethacrylate, UDMA= urethane dimethacrylate, Bis- EMA=Ethoxylated bisphenol A glycol dimaethacrylate.

Table 2: Overall means and standard deviations of flexural strength (MPa) for the two surface treatments in all immersion times for each material.

Storage time

Material	24 Hours Mean (SD)	1 Month Mean (SD)	3 Months Mean (SD)	6 Months Mean (SD)
Fuji II LC	34.5 ± (4.1)	49.1 ± (5.7)	44.6 ± (3.3)	28.7 ± (4.3)
Fuji II LC +	41.2 ± (6.5)	50.6 ± (8.7)	45.3 ± (6.1)	31.8 ± (4.2)
Total	37.8 ± (6.2)^{aA}	49.8 ± (5.8)^{a,B}	45 ± (4.9)^{a,B}	30.2 ± (4.3)^{a,C}
Fuji IX Fast	11.5 ± (3.4)	15.5 ± (1.5)	18.4 ± (2.5)	13.6 ± (3.8)
Fuji IX Fast+	14.6 ± (1.5)	17.2 ± (2.5)	17.1 ± (4)	16.2 ± 4.7)
Total	13.05 ± (2.9)^{b,A}	16.3 ± (1.8)^{c,AB}	17.7 ± (3.1)^{b,B}	14.9 ± (4.2)^{a,AB}
Gradia	79.9 ± (12.1)	52.7 ± (22.6)	55.3 ± (11)	46.7 ± (18.8)
Gradia +	80.3 ± (21.3)	59.8 ± (16.2)	79.9 ± (5.8)	71.8 ± (15.66)
Total	80.1 ± (16.2)^{c,A}	56.2 ± (19.8)^{a,B}	67.6 ± (15.3)^{c,A}	59.2 ± (21)^{b,A}
GæUF	107.9 ± (14.4)	90.8 ± (20.4)	85.3 ± (14.6)	51.3 ± (7.9)
GæUF +	108.4 ± (26)	89.7 ± (29.5)	78.7 ± (17.8)	78.5 ± (22.4)

Total	108.2 ± (19.8)^{d,A}	90.2 ± (20.1)^{d,AB}	82.04 ± (11.6)^{d,BC}	65.1 ± (21.2)^{b,C}
Rivalight	23.1 ± (4.8)	23 ± (12.8)	24.7 ± (5.2)	19.3 ± (2.8)
Riva light+	30 ± (6.3)	26.5 ± (2.02)	30.4 ± (8.4)	17.3 ± (1.9)
Total	26.6 ± (6.4)^{ab,A}	24.7 ± (8.9)^{c,AB}	27.6 ± (6.3)^{b,A}	18.3 ± (2.5)^{a,B}
Riva self	14.7 ± (2.5)	11.1 ± (1.02)	18.8 ± (3.4)	17 ± (2.7)
Riva self +	18.4 ± (3.8)	13.8 ± (5.8)	20.9 ± (3.7)	14.1 ± (2)
Total	16.6 ± (3.6)^{b,A}	12.4 ± (3)^{c,B}	19.85± (2.6)^{b,A}	15.6 ± (2.7)^{a,AB}
Luna	55.05 ± (32.7)	88.9 ± (13.5)	81.8 ± (13.5)	65.5 ± (11.4)
Luna +	54.2 ± (13.1)	80.6 ± (22.3)	96.2 ± (11.8)	71.3± (21.2)
Total	54.6 ± (23.5)^{ae,A}	84.7 ± (17.9)^{d,BC}	89 ± (11.5)^{d,BC}	69.9 ± (14.3)^{b,AC}

+ Indicates surface coated with G-Coat Plus

Different upper cases in each row indicate a significant difference ($p < 0.05$)

Different lower cases in each column indicate a significant difference ($p < 0.05$)

Table 3: Vickers hardness of the two surface treatments including p value in all immersion times for each material.

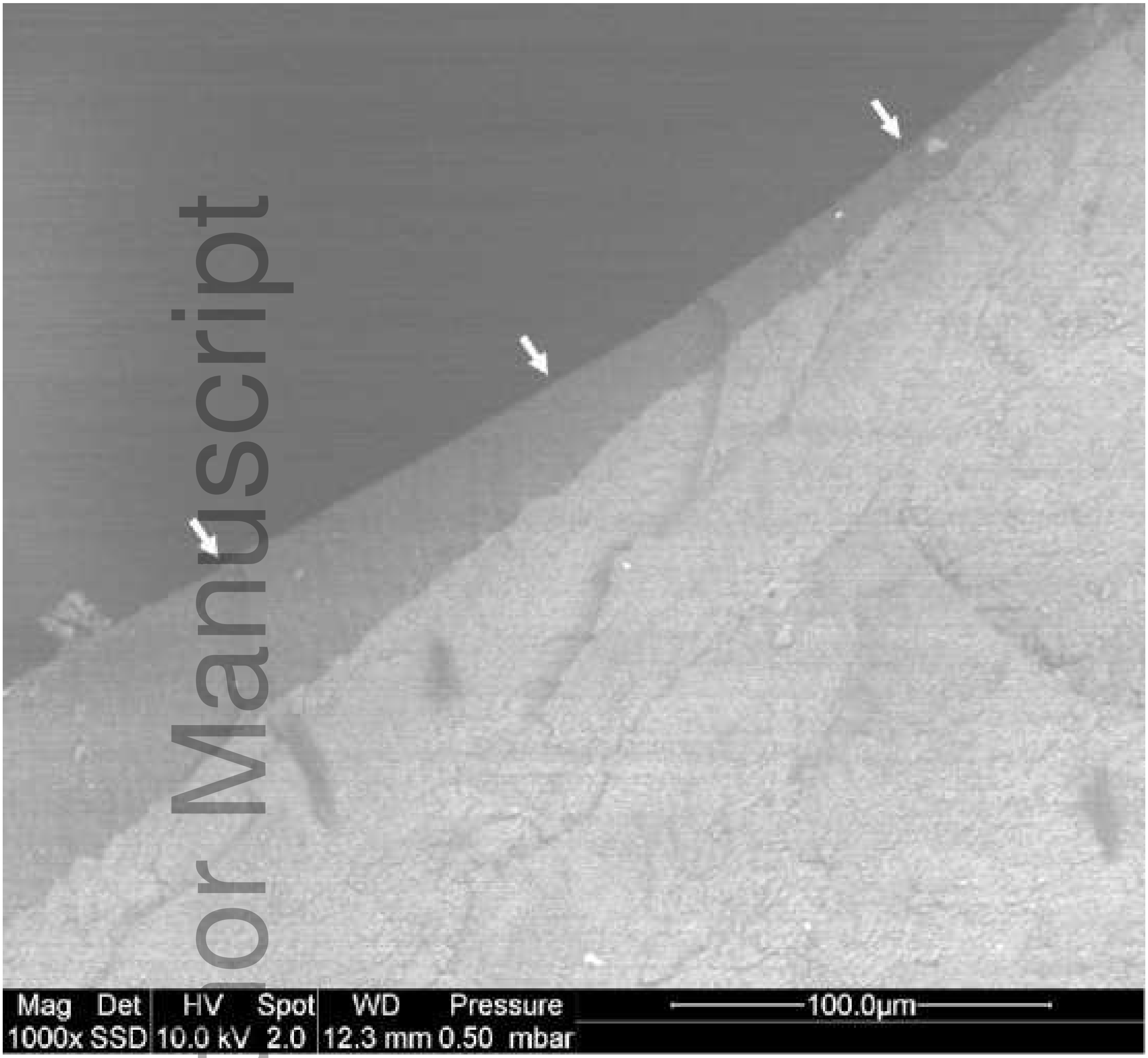
Storage time

Material	24 hours Mean (SD)	1 Month Mean (SD)	3 Month Mean (SD)	6 Month Mean (SD)
Fuji II LC	48.3 ± (6.7)^{a}	32.7 ± (6.5)^{b}	30.9 ± (3.4)^{b}	41.1 ± (4.3)^{c}
Fuji II LC+	29.8 ± (3.5) ^{a}	32.2 ± (6.1) ^{a}	30.4 ± (2.1) ^{a}	30.1 ± (4.5) ^{a}
P value	0.001	0.863	0.722	0.001
Fuji IX Fast	76.6(7.3) ^{a}	94.2 ± (5.7) ^{b}	86.1 ± (5.3) ^{c}	84.6 ± (4.7) ^{ac}
Fuji IX Fast+	40.5 ± (9.7) ^{a}	45 ± (9.5) ^{a}	63.4 ± (10.1) ^{b}	76.3 ± (8.6) ^{b}
P value	0.001	0.001	0.001	0.023
Gradia	43.9 ± (4.7) ^{a}	36.3 ± (3.2) ^{b}	41.5 ± (6.2)^{ab}	36.7 ± (3.4) ^{b}
Gradia+	37.1 ± (3.8) ^{a}	33.5 ± (3.2) ^{ac}	35.1 ± (4.5) ^{a}	28.8 ± (4.1) ^{c}
P value	0.04	0.077	0.025	0.001
GæUF	50.1 ± (3.9) ^{a}	44.8 ± (3.7) ^{a}	49.1 ± (3.7) ^{a}	49.5 ± (6.3) ^{a}
GæUF +	36.5 ± (4.4)^{abc}	40.9 ± (3.8)^{ab}	41.5 ± (4.2)^{ab}	34.1 ± (3.8) ^{ac}
P value	0.001	0.042	0.001	0.001
Riva light	46.2 ± (3.4) ^{a}	46.7 ± (6.6) ^{a}	45.5 ± (4.9) ^{a}	44.8 ± (5.8) ^{a}
Riva light+	33.3 ± (2.8) ^{a}	37.7 ± (2.2) ^{a}	34.3 ± (6.6) ^{a}	36.5 ± (4.4) ^{a}
P value	0.001	0.001	0.001	0.004
Riva self	60.5 ± (7.3) ^{a}	85.1 ± (17.8) ^{b}	75.1 ± (6.4)^{ab}	75.3 ± (18.1)^{ab}
Riva self+	41.9 ± (14.8) ^{a}	49.4 ± (12.9) ^{a}	51.4 ± (11.3) ^{a}	45.8 ± (11.3) ^{a}
P value	0.006	0.001	0.001	0.001
Luna	64.5 ± (7.3) ^{a}	63.1 ± (9.8)^{a}	65.1 ± (6.4)^{a}	56.3 ± (10) ^{b}
Luna+	51.9 ± (14.8)	41.4 ± (12.9)	46.4 ± (11.3)	40.8 ± (11.3)
P value	0.001	0.001	0.001	0.002

+ means surface coated with G-Coat Plus

Different lower case letters show significant differences between times intervals in each row.

P value shows statistical differences between coated and uncoated for each material



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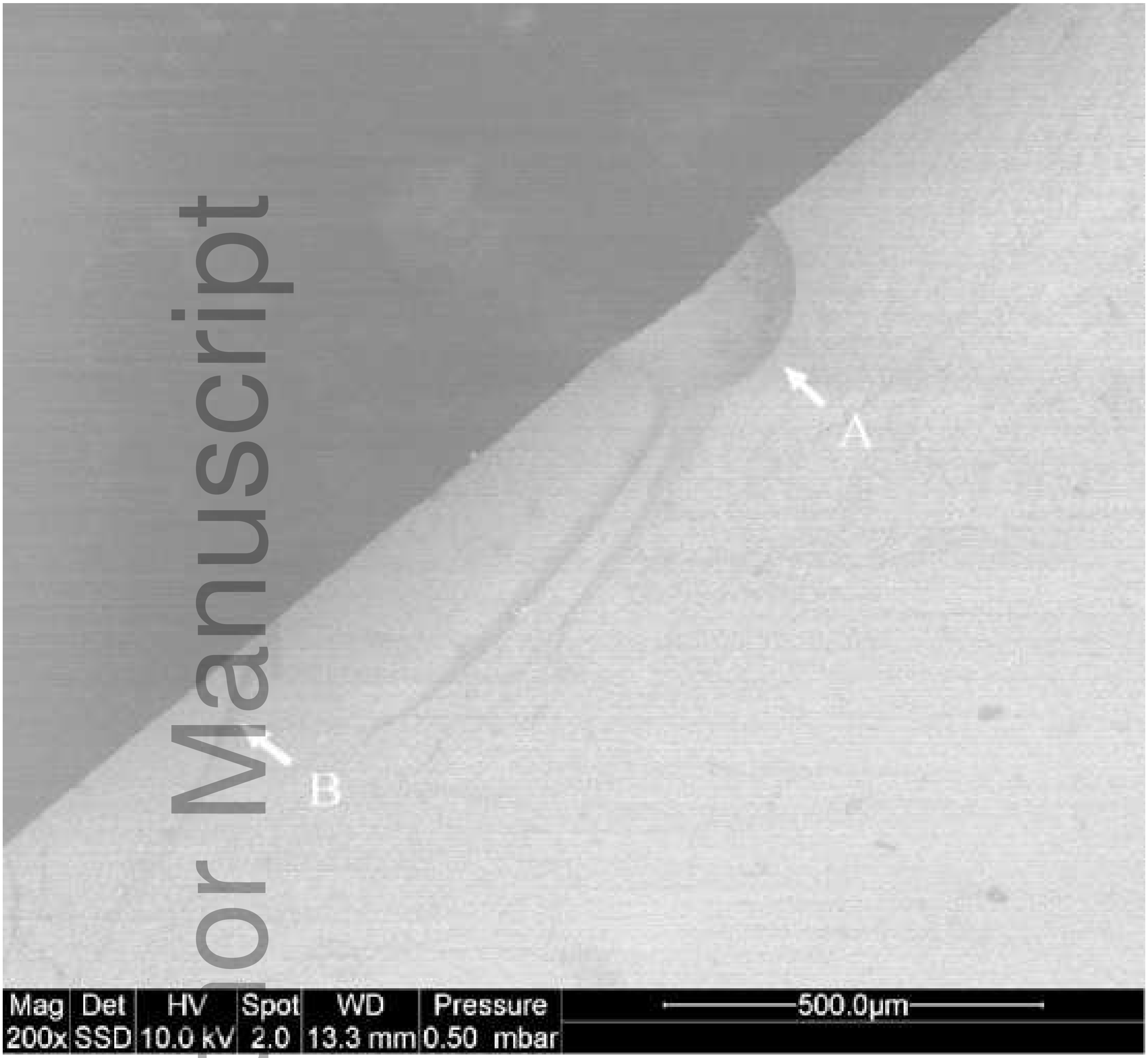

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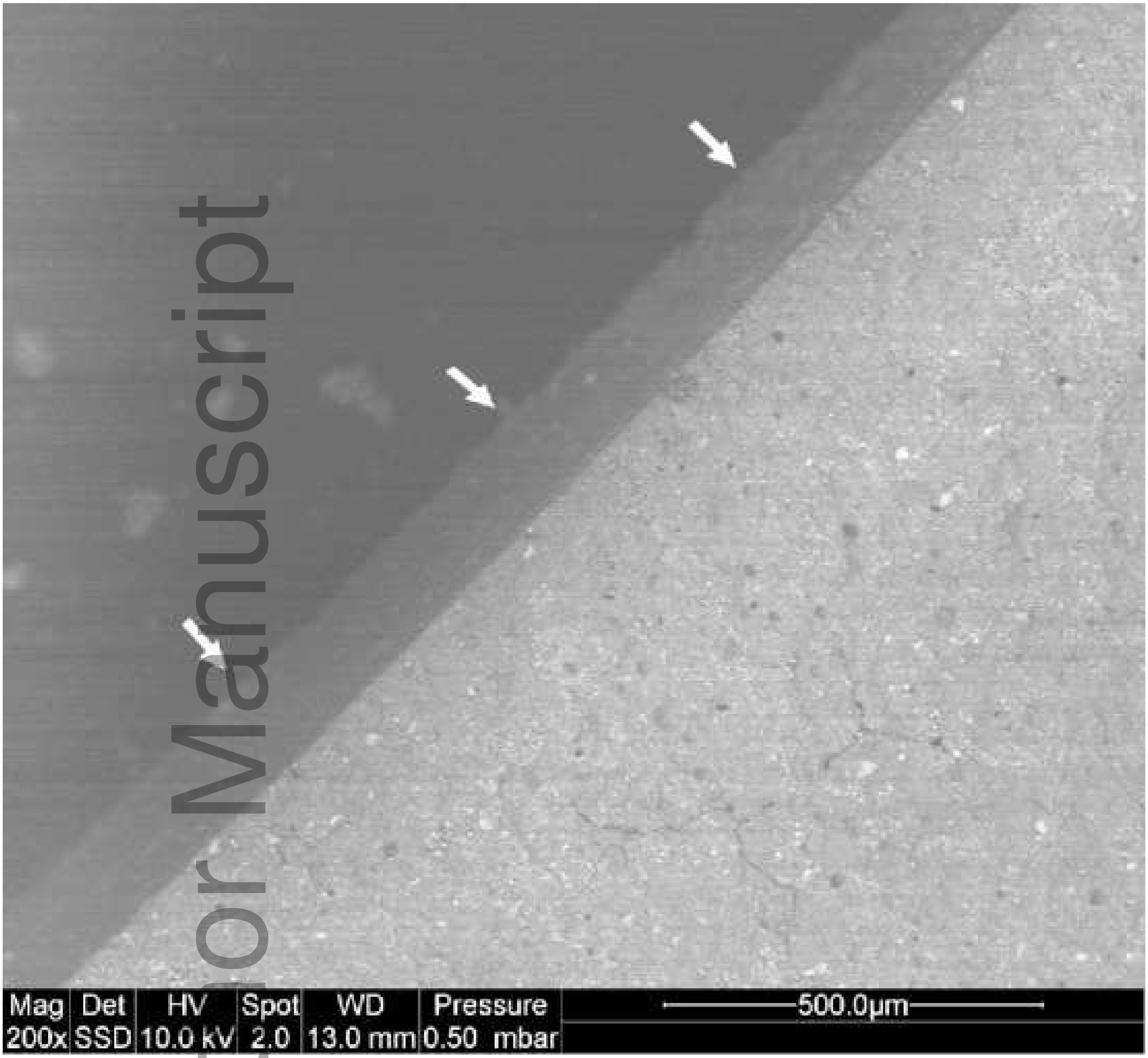

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