EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 68, 995:1002, January, 2022
Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 17-10-2021 • Accept Date : 28-11-2021 • Available online: 30-01-2022 • DOI : 10.21608/edj.2021.101520.1833

EFFECT OF AIR ABRASION PRESSURE AND CAD/CAM MILLING ON MICROTENSILE BOND STRENGTH OF REINFORCED COMPOSITE INLAYS TO IMMEDIATELY SEALED DENTIN: AN INVITRO COMPARATIVE STUDY

Mai Mamdouh Akah* *and* Eman Ezzat Yousef**

ABSTRACT

Objectives: The aim of this study was to evaluate the microtensile bond strength of CAD-CAM fabricated reinforced composite (Brilliant Crios) inlays to immediately sealed dentin surface in absence of air abrasion, depending only on the roughness produced by the CAD/CAM milling tools, and after sandblasting the fitting surface at high pressure, after artificial aging.

Materials and Methods: Standardized occlusal cavities were prepared in extracted molar teeth to receive inlay restorations. All prepared cavities received immediate dentin sealing treatment. Brilliant Crios inlay restorations were individually designed and milled utilizing CAD/CAM system. Specimens were randomly divided into two equal groups according to the surface treatment applied to the fitting surface of the restoration before cementation; Group I: No treatment (CAD/CAM milled surface), Group II: Post-milling air abrasion at high pressure. All specimens were then subjected to thermocycling, followed by microtensile bond strength testing. Independent samples T-tests were used to evaluate the results.

Results: The mean microtensile bond strength of Group I was 11.99 MPa ± 0.45, while that of Group II was 10.91 MPa ± 0.24. A statistically significant difference between the tested groups was found ($p=0.040$).

Conclusions: In the absence of adhesive layer application to the fitting surface of Brilliant Crios inlay restorations, the surface roughness produced by CAD/CAM milling solely had the ability to establish a better bond after artificial aging compared to that established after air abrasion at high pressure.

KEY WORDS: CAD/CAM, Inlay, Microtensile, Immediate Dentin Sealing, Air Abrasion

* Associate Professor , Conservative Dentistry Lecturer, Cairo University, Cairo, Egypt
** Fixed Prosthodontic Department, Cairo University

INTRODUCTION

Indirect esthetic restorations of large cavities; such as inlays and onlays, have become widely used nowadays. Their use increased in an attempt to overcome the drawbacks of direct composite resin restorations, which included polymerization shrinkage with subsequent gap formation, marginal integrity deterioration, and postoperative sensitivity especially in posterior teeth. [1-2] These drawbacks also involved difficulty in reproducing proper proximal contour and contact, contact area instability, reduced mechanical properties, poor wear resistance and color instability.[1-2] All these factors adversely affected the success and longevity of direct restorations.[2]

Dental ceramics have been successfully used for many years for indirect restoration construction. However, their high elastic modulus and brittleness reduced their ability to absorb high forces.[2.] This led to introduction of novel hybrid materials; such as reinforced composite blocks, to be used as a reliable alternative to dental ceramics. They offered the advantages of CAD/CAM technology including ease, speed and patients satisfaction. [1,3] In addition, the material itself offered easy machinability, adjustments, and reparability together with enhanced resilience, lower elastic modulus and brittleness in comparison to dental ceramics. [4]

However, the success of indirect restorations does not depend only on the material nature, but on proper bonding as well. In order to enhance bonding to tooth structure various techniques were employed, one of which was immediate dentin sealing (IDS). It involved applying and polymerizing dentin bonding agent to freshly cut dentin before making an impression or provisionalization.[2.] This concept enhanced the bond strength to the luting agent, protected dentin against any bacterial leakage and hypersensitivity until the final cementation of the restoration. [2]

The presence of a durable bond between the cement and the restoration also influences the long-term survival of the restoration. Poor bonding may reduce the fracture strength, retention and marginal fit of the restoration.[5] Thus, several treatments of the fitting surface of the restorations were utilized. Indirect reinforced composite resin (RCR) restorations are conventionally air abraded prior to cementation. Such treatment aimed to increase surface roughness, rendering it micro-retentive, enabling the mechanical interlocking of the resin cement and hence enhancing the restoration retentive bond strength and reducing microleakage. [2,3,5] However, the optimal parameters of air abrasion such as sandblasting pressure to achieve the surface roughness necessary for durable bonding are still controversial. [6]

In addition, in clinical situations, after the restoration fit is verified intraorally, the restoration's fitting surface becomes contaminated with saliva and debris. In such situations, the clinician is urged to perform chair-side sandblasting if available. If not, the clinician would be obligated to resend the restoration to the dental laboratory for fitting surface retreatment. These procedures are considered time consuming. In addition, sandblasting itself is technique sensitive.[7] Furthermore, CAD/CAM milling procedures are well known to significantly increase the surface roughness of ceramics and composite materials. [8,9] However, the effect of such roughness solely on the restoration bond strength is not fully understood.

Thus, the aim of the present study was to evaluate the micro-tensile bond strength of indirect composite resin inlay restorations manufactured using CAD/CAM technology to teeth in absence of any sandblasting, depending only on the roughness produced by the CAD/CAM milling tools, and after sandblasting the fitting surface at high pressure. The null hypothesis was that would be no difference in the influence of both techniques on the micro-tensile bond strength.

MATERIALS AND METHODS

Materials

The type of the materials used in the study, their composition and manufacturers are listed in Table 1.

Tooth selection and cavity preparation

A total of ten freshly extracted, caries and defect-free human third molars were selected and stored in distilled water throughout the study. All teeth received a standardized occlusal Class-I cavity for inlay restorations. The dimensions of each prepared cavity was 5 mm mesio-distally, 4 mm bucco-lingually and 4 mm in depth. Teeth preparation was performed free-hand by a single operator to simulate the clinical situation, using standardized short diamond burs (DIA-BURS, SF-31SC, Mani, INC, Japan) attached to a high-speed air-turbine under water cooling. The bur was replaced after every five cavity preparations. The final dimensions of the prepared cavities were verified with a periodontal probe and a digital caliper (Digimatic Caliper, Mitutoyo, Tokyo, Japan).

Teeth pretreatment (Immediate dentin sealing)

After cavity preparation, all exposed cavity dentin surfaces were immediately sealed using All-Bond Universal adhesive following the manufacturer's instructions in a self-etch mode. During this procedure, two separate coats of the adhesive were applied to the dentin surfaces and gently scrubbed with a micro-brush for 10-15 sec per coat with no light polymerization between coats. The applied coats were air blotted with air syringe for at least 10 sec per coat until no longer movement to evaporate any excess solvent. The Light polymerization was then carried out for 10 sec at 1200 Mw/cm^2 using the Bluephase light-curing unit (Ivoclar Vivadent, Schaan, Liechtenstein).

TABLE (1): Materials used in this study

Material	Type	Composition	Manufacturer
BRILLIANT Crios	Reinforced Resin composite CAD/CAM blocks	Inorganic filler content (71 wt%): <20 nm amorphous silica sio_2 , < 1 µm barium glass. Polymers (29 wt%): Cross-linked methacrylates (Bis-GMA, BIS-EMA, TEGDMA)	Coltene/Whaledent AG, Switzerland
All-Bond Universal	Universal light cured adhesive system	MDP, Bis-GMA, HEMA, ethanol, and water.	Bisco, Schaumburg, IL, USA
G-Cem	Self-adhesive dual cure resin cement	Powder: fluoroaluminosilicate glass, initiator, pigment. Liquid: 4-META, phosphoric acid ester monomer, water, UDMA, dimethacrylate, silica powder, initiator, stabilizer 65–70 %wt	GC Corp., Tokyo, Japan

Bis-GMA: bisphenol A-diglycidylmethacrylate, Bis-EMA: ethoxylated bisphenol A-diglycidylmethacrylate, TEGDMA: triethyleneglycol dimethacrylate, MDP: 10-methacryloyloxydecyl dihydrogen phosphate, HEMA: 2-hydroxyethyl methacrylate, 4-META: 4-methacryloxyethyl trimellitic acid, UDMA: urethane dimethacrylate

Restorations fabrication

All prepared cavities were digitally scanned utilizing 3Shape TRIOS 3 intraoral scanner (3Shape, Copenhagen, Denmark) in accordance with the manufacturer's instructions. The scanned files were saved as STL files and exported to the laboratory for restoration designing and milling using CEREC MCXL milling machine (Dentsply Sirona, York, Pennsylvania, United States) (figure 1).

Sample grouping and surface treatment of the restorations

Specimens were randomly divided into two equal groups according to the surface treatment applied to the fitting surface of the restoration before cementation; Group I: No treatment (CAD/CAM milled surface), Group II: Post-milling air abrasion at high pressure. In Group I, the inlays remained untreated, while in Group II, the fitting surface of the inlays were air abraded for 10 sec following the manufacturer's instructions with 50 µm Al_2O_3 particles at a distance of 10 mm, at a 45° angle to avoid any chipping in the restoration margins, but at 4 bar pressure. Air abrasion was carried out free hand to simulate the clinical situation, and by a single operator as shown in figure (2). The restorations were then cleaned and carefully dried with compressed air.

Cementation procedures

G-Cem self-adhesive resin cement was applied to the fitting surface of each inlay, which was immediately seated within its corresponding prepared tooth and stabilized in place with moderate finger pressure simulating the clinical situation. The restoration was tack cured for 2 seconds using a light curing unit (Bluephase light-curing unit, Ivoclar Vivadent, Schaan, Liechtenstein), the excess cement was then removed with the tip of an explorer and the final light polymerization was carried out for 20 seconds per surface. The restored molars were then left to allow the cement self-curing for 4 minutes before finishing and polishing the margins.

Thermocycling

The restored molars were stored in distilled water for 24 hours at a temperature of 37°C prior to artificial aging. Specimens were subjected to thermocycling (THE-100 SD Mechatronic Thermocycler, Germany) for 1000 cycles between 5°C and 55°C, with a dwell time of 30 seconds and a transfer time of 10 seconds. [10, 11] Thermocycling was carried out to simulate the temperature changes that take place in the oral cavity. [12]

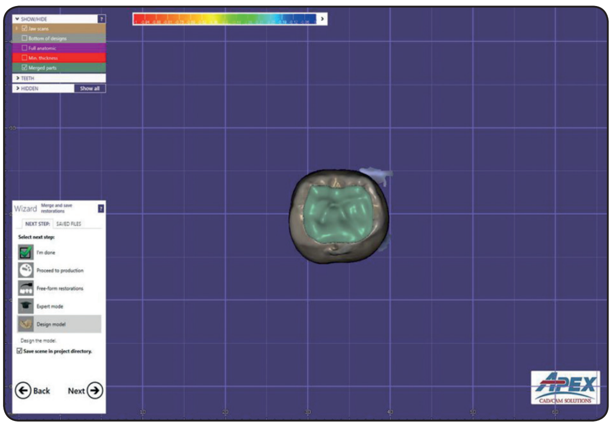

Fig. (1) The virtually designed restoration

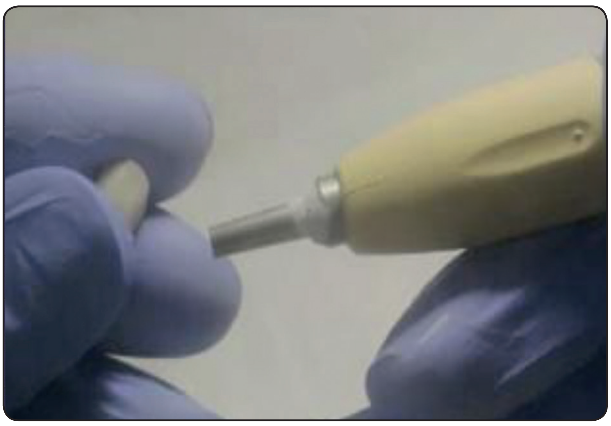

Fig. (2): Air abrasion of the fitting surface of the restoration.

Microtensile bond strength (µTBS) testing

a) Restoration-cement-dentin sticks preparation

Each restored molar was then mounted in an automated diamond saw (Isomet 4000, Buehler Ltd., Lake Bluff, IL, USA), where they had their occlusal surfaces flattened to the level of the dentino-enamel junction under copious water coolant. Afterwards, teeth were sectioned longitudinally in the mesio-distal and buccal-lingual directions across the bonded interface, to obtain 3 central rectangular restoration-cement-dentin sticks from each tooth (15 sticks per group) with a cross sectional thickness of 0.9±0.1 mm [13, 14] and 5.5±0.1 mm length. The exact dimensions of the obtained sticks were verified with a digital caliper (Digimatic Caliper, Mitutoyo, Tokyo, Japan). The sticks were then stored in distilled water at room temperature in a labeled small tight-seal plastic container.

b) Testing procedures

Each rectangular restoration-cement-dentin stick was attached to Geraldeli's jig, which was used to mount the sticks onto the universal testing machine (Instron, MA, USA). Each stick was aligned in the central groove of the jig and glued in place by its ends using cyanoacrylate based glue (Zapit, DVA Inc, USA). The sticks were then stressed under tension in a universal testing machine (Instron, MA, USA) with a load cell of 500 N. Tensile load was applied, at a cross-head speed of 0.5 mm/min, until bonding failure of the specimen occurred. The bond strength values were then converted in MPa. This was done using; Bluehill Lite software, (Instron, MA, USA) by dividing the imposed force at the time of fracture (in N) by the premeasured cross-sectional bonded area (in mm^2). [10, 15]

Statistical analysis

Data was collected, tabulated and statistically analyzed. The mean and standard deviation values were calculated for each group. Data was explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, where it showed parametric (normal) distribution. Independent sample t-test was used to compare the obtained mean values of the tested groups. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows (SPSS, Chicago, IL, USA).

RESULTS

There was a statistically significant difference between the tested groups where p=0.040. The highest mean value was found in Group I (11.99 MPa±0.45), while the least mean value was found in Group II (10.91±0.24). The obtained results are shown in Table 2.

TABLE (2): The mean (MPa) and standard deviation values of µTBS of the tested groups

Variables	Micro-tensile bond strength	
	Mean	**SD**
Group I	11.99^{a}	0.45
Group II	10.91^{b}	0.24
p-value	**0.040***	

Means with different letters in the same column indicates significant difference, *: significant (p<0.05)

DISCUSSION

A strong, durable bond can influence the longevity of indirect restorations, improves their marginal adaptation, inhibits any microleakage and promotes the fracture resistance of the restored tooth and restoration.[16] Bonding to indirect restorations depends on micromechanical interlocking and chemical bonding.[16] In case of Brilliant Crios, air abrasion was routinely employed to increase the surface area and create micro-irregularities, into which the adhesive resin would flow and interlock, forming a strong micromechanical bond. [3,16] In previous literature such as *Papadopoulos C. et al. 2021* [15] *and Günal-Abduljalil B. et al. 2021*[5] it was proved that performing air abrasion according to the manufacturer's instructions enhanced the bond strength. However, the micromechanical interlocking is strongly dependent on surface roughness and surface morphology. [3] Thus, several studies were conducted to test other methods of surface treatments such as hydrofluoric acid etching, silane application,[15, 17] laser surface treatments and others to induce different degrees of surface roughness, others tested manipulating the air abrasion parameters such as *Strasser T. et al 2018*,[6] in an attempt to show the best conditioning method.

In the present study, performing air abrasion with increased pressure was tested while using small-sized abrading particles as recommended by the manufacturer to determine the effect of the assumed deeper surface roughness produced in comparison to that produced by the milling tools of the CAD/CAM systems solely. Although recommended by the manufacturer, no adhesive layer was applied to the fitting surface of the restoration prior to cementation. This allowed the results to reveal the true effect of the micromechanical surface treatment solely.

The tested restorations were bonded to natural human teeth, in order to simulate the clinical situations rendering reliable results. The teeth used were prepared to receive inlay restorations rather than just sectioned or flattened as employed in other studies such as *D'Arcangelo et al. 2007*.[18] In fact, very little studies tested the microtensile bond strength in inlays evaluating the bond strength obtained with the intra-cavity walls. [19] Class I cavities employed in the present study are known to suffer from the adverse effect of configuration factor (C-factor), this factor is known to cause stresses within the cement layer as a result of cement shrinkage after polymerization. [12] Such stresses could affect the bond strength. [12] Choosing this cavity preparation design allowed realistic mimicking to the clinical challenges, where the preparation design plays an important role in the long-term success of the restoration bonding.

The preparation was proceeded free hand to simulate the clinical situation, performed by a single operator fulfilling specific dimensions, which were meticulously verified to ensure standardization. All cavity preparation procedures were done under water cooling conditions to eliminate any heat generating with subsequent teeth weakening and cracking. Although a 1.5-2 mm cavity depth [20] was ideally recommended, the depth of the prepared cavities was standardized at 4 mm to simulate deep cavity preparations. In addition, a dual cured resin cement was used which was believed to alleviate this factor.

All prepared cavities received IDS to ensure better bonding to the tooth structure, aiming to focus only on the cement/material interface and alleviate any other confounding factors. The cement used in the present study was self-adhesive in nature. Its use allowed easy, short cementation procedure with reduced technical errors compared to total etch and adhesive cements, which required additional technique sensitive steps. [21]

The quantitative µTBS test was employed in the present study, as it is believed to provide easy to understand data that can be simply related to the bond strength. [19] It was used rather than shear bond strength test, as it was claimed that the small size of the tested specimens produced more favorable stress distribution during testing, allowing the resulting failure to be closer to their true ultimate values.[16]

Based on the results of the present study, the null hypothesis was rejected. The results showed that the bond strength was significantly affected by high-pressure air abrasion, where absence of air abrasion showed the highest results. Our result were confirmed by the results obtained by *Strasser T. et al 2018*,[6] who found that increasing the sandblasting pressure to 2bar instead of 1bar, cause slight crack formation in the surface whether using small sized abrading particles (50µ) or large sized particles (120 µ). Regarding the results of our study, the reduced µTBS after air abrasion might be due to many factors. Inducing surface roughness through air abrasion with high pressure most probably caused minute micro-cracks, [6] that might have been increased by thermocycling, causing restoration failure. On the other hand, the surface roughness produced during CAD/CAM milling solely did not adversely affect the restoration surface. The reduced μTBS after air abrasion might also be due to the inability of the cement to flow into the produced roughness, especially in the absence of the adhesive layer. Moreover, the possible formation of minute air entrapments, which in turn could have jeopardized the intimate contact of the cement to the restoration surface. Although thermocycling is known to cause deterioration of the cement layer, [12] it cannot be considered as the main cause of the present result, since both groups were subjected to the same aging procedures. However, it can only be assumed to aggravate the situation.

CONCLUSION

Within the limitation of the present study, it was found that, in the absence of adhesive layer application to the fitting surface of Brilliant Crios inlay restorations, the surface roughness produced by CAD/CAM milling solely had the ability to establish a better bond after artificial aging compared to that established after air abrasion at high pressure. Increasing the air abrasion pressure adversely affected the durable bond after artificial aging. To enhance Brilliant Crios restorations bond strength, sandblasting with small abrading grain size and low pressure should be employed. Further research is recommended to test different parameters of air abrasion with and without the adhesive layer application, and after increased thermodynamic loading.

Funding and conflict of interests

The present study was self-funded, and the authors of the present study declared that they had no financial or personal interest of any nature or kind in any of the products, services, and/or companies that were presented in this research.

REFERENCES

1. Ishii N, Maseki T, Nara Y. Bonding state of metal-free CAD/CAM onlay restoration after cyclic loading with and without immediate dentin sealing. Dent Mater J. 2017 May 31;36(3):357-367.
2. D'Arcangelo C, Vanini L, Casinelli M, Frascaria M, De Angelis F, Vadini M, D›Amario M. Adhesive cementation of indirect composite inlays and onlays: A literature review. Compend Contin Educ Dent. 2015 Sep;36(8):570-7; quiz 578.
3. Papadopoulos K, Pahinis K, Saltidou K, Dionysopoulos D, Tsitrou E. Evaluation of the surface characteristics of dental CAD/CAM materials after different surface treatments. Materials (Basel). 2020 Feb 22;13(4):981.
4. El Zohairy AA, De Gee AJ, Mohsen MM, Feilzer AJ. Microtensile bond strength testing of luting cements to prefabricated CAD/CAM ceramic and composite blocks. Dent Mater. 2003 Nov;19(7):575-83.
5. Günal-Abduljalil B, Önöral Ö, Ongun S. Micro-shear bond strengths of resin-matrix ceramics subjected to different surface conditioning strategies with or without coupling agent application. J Adv Prosthodont. 2021 Jun;13(3):180-190.
6. Strasser T, Preis V, Behr M, Rosentritt M. Roughness, surface energy, and superficial damages of CAD/CAM materials after surface treatment. Clin Oral Investig. 2018 Nov;22(8):2787-2797.
7. Reymus M, Roos M, Eichberger M, Edelhoff D, Hickel R, Stawarczyk B. Bonding to new CAD/CAM resin composites: Influence of air abrasion and conditioning agents as pretreatment strategy. Clin Oral Investig. 2019 Feb;23(2):529-538.
8. Matsumura M, Nozaki K, Yanaka W, Nemoto R, Takita M, Yamashita K, Matsumura M, Miura H. Optimization of milling condition of composite resin blocks for CAD/CAM to improve surface roughness and flexural strength. Dent Mater J. 2020 Dec 3;39(6):1057-1063.
9. Mota EG, Smidt LN, Fracasso LM, Burnett LH Jr, Spohr AM. The effect of milling and postmilling procedures on the surface roughness of CAD/CAM materials. J Esthet Restor Dent. 2017 Nov 12;29(6):450-458.
10. Poptani B, Gohil KS, Ganjiwale J, Shukla M. Microtensile dentin bond strength of fifth with five seventh-generation dentin bonding agents after thermocycling: An in vitro study. Contemp Clin Dent. 2012 Sep;3(Suppl 2):S167-71.

11. Trajtenberg CP, Caram SJ, Kiat-amnuay S. Microleakage of all-ceramic crowns using self-etching resin luting agents. Oper Dent. 2008 Jul-Aug;33(4):392-9.

12. Rozan S, Takahashi R, Nikaido T, Tichy A, Tagami J. CAD/CAM-fabricated inlay restorations: Can the resin-coating technique improve bond strength and internal adaptation? Dent Mater J. 2020 Dec 3;39(6):941-949.

13. Mohamed NI, Safy RK, Elezz AFA. Microtensile bond strength, marginal leakage, and antibacterial effect of bulk fill resin composite with alkaline fillers versus incremental nanohybrid composite resin. Eur J Dent. 2021 Jul;15(3):425-432.

14. van den Breemer C, Özcan M, Cune MS, Ayres AA, Van Meerbeek B, Gresnigt M. Effect of immediate dentin sealing and surface conditioning on the microtensile bond strength of resin-based composite to dentin. Oper Dent. 2019 Nov/Dec;44(6):E289-E298.

15. Papadopoulos C, Dionysopoulos D, Pahinis K, Koulaouzidou E, Tolidis K. Microtensile bond strength between resin-matrix CAD/CAM ceramics and resin cement after various surface modifications and artificial aging. J Adhes Dent. 2021 Jun 5;23(3):255-265.

16. Oztürk AN, Inan O, Inan E, Oztürk B. Microtensile bond strength of CAD-CAM and pressed-ceramic inlays to dentin. Eur J Dent. 2007 Apr;1(2):91-6.

17. Emsermann I, Eggmann F, Krastl G, Weiger R, Amato J. Influence of pretreatment methods on the adhesion of composite and polymer infiltrated ceramic CAD-CAM blocks. J Adhes Dent. 2019;21(5):433-443.

18. D'Arcangelo C, Vanini L. Effect of three surface treatments on the adhesive properties of indirect composite restorations. J Adhes Dent. 2007 Jun;9(3):319-26.

19. Koshida S, Maeno M, Nara Y. Effect of differences in the type of restoration and adhesive resin cement system on the bonding of CAD/CAM ceramic restorations. Dent Mater J. 2020 Dec 3;39(6):1022-1032.

20. Da Silva D, Ceballos L, Fuentes MV. Influence of the adhesive strategy in the sealing ability of resin composite inlays after deep margin elevation. J Clin Exp Dent. 2021 Sep 1;13(9):e886-e893.

21. Kavut I, Uğur M, Tanrıkut Ö. Evaluation of the adhesion of different CAD/CAM materials with self etch/adhesive resin cements. IOSR-JDMS. 2019;18(2):51-54.