

NADER SAADEDDIN
MANAR ALI AL-KHALIL
OMAR AL-ADEL

Department of Fixed Prosthodontics, Faculty of Dentistry, Damascus University, Damascus, the Syrian Arab Republic

CORRESPONDENCE

Dr. MHD Nader Saadeddin
Department of Fixed Prosthodontics
Faculty of Dentistry
Damascus University
Damascus, the Syrian Arab Republic
Tel. +963 933 88 88 45
E-mail:
dds.nader.syria@gmail.com

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Effect of immediate dentin sealing on the fracture strength of lithium disilicate ceramic onlays

KEYWORDS

Immediate dentin sealing
Fracture strength
Onlay restoration
Glass-ceramic

SUMMARY

This study aimed to evaluate the effect of immediate dentin sealing (IDS) on the fracture strength of ceramic onlays when compared with delayed dentin sealing (DDS). Twenty extracted human maxillary premolars were randomly divided into 2 groups according to the dentin sealing technique ($n = 10$). A standardised mesio-occlusal-distal cavity was prepared with reduction of the palatal cusp. The dentin surfaces of the IDS group were immediately sealed after finishing the preparation (before taking impressions, temporisation, and 14-day storage at 37°C) using a bonding system (ALL-BOND 3[®], ALL-BOND 3[®] RESIN) and flowable composite (Te-Econom Flow). Impressions were made, and temporary restorations were fabricated using PRO-V FILL[®]. The wax patterns were milled, and the onlays were fabricated by heat-pressing technique (IPS e.max Press). After bonding the

final restorations with resin cement (Variolink N), the specimens were thermocycled. Fracture strength was measured using a universal testing machine (Testometric M350-10KN) at 1 mm/min until failure occurred. Student's t-test was used to evaluate the results of the fracture strength test. The failure mode was examined using a stereomicroscope. The mean fracture strength in the IDS group (1335 ± 335 N) was statistically significantly higher than that for the DDS group (931 ± 274 N) ($p < 0.05$). Fracture of the restoration with a small portion of the tooth was the most frequent mode of failure. Within the limitation of this in vitro study, there was an improvement in the fracture strength of ceramic onlays with the use of IDS. However, the ceramic onlays were strong enough to withstand the physiological mastication force in both groups.

Introduction

Restoration of teeth in the posterior area of the oral cavity is considered a challenge for dentists today. It is necessary to fulfill the increasing cosmetic demands and meet the expectations of patients while ensuring the functional aspect and maintaining dental tissues. Restorations are expected to provide excellent long-term durability and prognosis. The restoration options of class-I and class-II cavities include direct composite restorations, indirect composite inlays and onlays, and ceramic partial coverage restorations.

When compared to posterior composite restorations especially in larger cavities/preparations, ceramic partial coverage restorations are considered the best option, both aesthetically and in terms of durability. These restorations are considered excellent alternatives for complete coverage restorations that cause an extensive loss in dental hard tissues. The amount of the preparation of a complete crown is 67.5%–75.6% of the whole dental tissue, while the partial preparations remove merely 5.5%–27% (EDELHOFF & SORENSEN 2002). This can influence the longevity of the restoration and the tooth at the same time (CHRISTENSEN 2008).

Thanks to the development of the materials and strategies of adhesion, partial coverage ceramic restorations have become a clinical option. Different systems of ceramics have been used for the fabrication of these restorations. The most important one is the system of heat-pressed lithium disilicate glass-ceramic, as this ceramic has distinctive optical and mechanical properties and a high fracture strength (STAPPERT ET AL. 2007). Due to its microstructure, it can be acid-etched. Consequently, the bond strength with resin cements is high (ROCCA ET AL. 2015). High survival rates have also been recorded for partial coverage restorations made of lithium disilicate glass-ceramic (SASSE ET AL. 2015; AL-AKHALI ET AL. 2017).

The success of dentin bonding with resin materials is the cornerstone in the success of onlays, due to the fact that the final strength of the tooth-restoration complex mainly depends on the adhesion procedures, especially with the high possibility of dentin exposures during the preparation of such restorations. In this context, the management of dental tissues after the completion of the preparation is considered an important matter in increasing the chances of successful treatment. The immediate dentin sealing method was proposed to improve the bonding in the early 1990s by Dr. Shigehisa Inokoshi, the Godfather of contemporary “Immediate Dentin Sealing” and “Cavity Design Optimization” techniques using resin materials. He published an article in Japanese in which he described the dentin sealing and pulp protection under the name of “Resin Coating” technique (INOKOSHI 1992). In 1992, Pashley had approached the subject as well; he and his team proposed to seal dentin by only using an adhesive (PASHLEY ET AL. 1992), while Inokoshi used a flowable with an adhesive. The technique was further developed by establishing a resin sealing layer on the surface of dentin by applying a bonding system plus a low-viscosity composite resin. It is believed that this base layer of the composite resin insulates and protects the underlying hybrid layer, and consequently this should help to preserve the dentin seal (DUARTE ET AL. 2006).

With immediate dentin sealing, it has been observed that there is a better relief for the patient with less bacterial micro-leakage and dental sensitivity during the temporisation phase and after cementation procedure (HU & ZHU 2010; QANUNGO ET AL. 2016). Therefore, the technique of immediate dentin sealing was

proposed when there are widely exposed dentin areas, like the preparations for indirect restorations, such as inlays, onlays, and full crowns. Moreover, some investigations also observed that the bond strength is much better with freshly cut dentin than with the dentin contaminated with temporary cement residues (LEE & PARK 2009). The immediate dentin sealing technique allows for pre-polymerisation of the dentin bonding agent, which contributes to improving durability of the bonding layer (MAGNE ET AL. 2005; OKUDA ET AL. 2007; MAGNE 2014; GRESNIGT ET AL. 2016).

Clinically, the most common reason for ceramic partial coverage restorations failure is restoration fracture, followed by failure of endodontic treatments and secondary caries (MORIMOTO ET AL. 2016). In a study about the clinical success of inlays and onlays made of glass-ceramic over a 12-year period, bulk fracture was the main reason of failure, due to the fragility of the ceramic structure (FRANKENBERGER ET AL. 2008). Hence, fracture strength is regarded a crucial issue in the ceramic partial restorations and a qualitative criterion for evaluating the durability of prosthesis. However, there appears to be insufficient data on the effect of immediate dentin sealing technique on onlay fracture strength.

The aim of this study was to investigate the fracture strength of lithium disilicate ceramic onlays after applying the immediate dentin sealing technique and comparing it to delayed dentin sealing. The null hypothesis was that the immediate dentin sealing technique would not affect the fracture strength of the ceramic onlays under the conditions of this study.

Materials and methods

Specimen preparation

The sample of the study consisted of 20 maxillary premolars that were restored with onlays. The onlays were fabricated using heat-pressed lithium disilicate glass-ceramic. Twenty premolars freshly extracted for orthodontic reasons were collected. The teeth were sound, free of lesions and cracks, and had close dimensions (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION 2003). They were cleaned of any tissue remnants or calculus residues using dental curettes, hand scalers, and air scaler tips. After that, they were preserved in an aqueous solution of 0.05% of thymol at room temperature until the start of the study. Then, they were stored in an aqueous solution of 0.9% of sodium chloride. The premolars were randomly divided according to the dentin sealing technique into 2 stratified groups (n = 10, each): immediate dentin sealing (IDS) and delayed dentin sealing (DDS).

A putty condensation silicone mold was used to make cuboid acrylic bases (18 × 18 × 13 mm³), where the teeth roots were immersed in a transparent self-cured acrylic resin (Orthocryl®, Dentaaurum, Ispringen, Germany) perpendicular to the horizontal surface of the mold and 1 mm below the cemento-enamel junction (CEJ). A silicone guide was made for each premolar to copy the anatomical shape in order to check later the thickness of the preparation. Furthermore, 20 perforated custom trays were made of self-cured acrylic resin (RESPAL® NF, SPD, Mula-zzano [LO], Italy) for making the final impression.

Tooth preparation

Twenty standardised mesio-occlusal-distal (MOD) preparations with reduction of the palatal cusp were performed using the set of burs for ceramic inlays and partial crowns (Expert Set 4562; Komet Dental, Gebr. Brasseler GmbH & Co. KG, Lemgo,



Fig.1 The dimensions of the tooth preparation. On the left: proximal view. On the right: occlusal view

Germany). The dimensions of the preparations were standardised using gingival probe, iwanson caliper, and split silicone guide (Fig.1). The walls after the preparation were smooth and relatively flat, the gingival-occlusal divergence of the axial walls was 6 to 10 degrees per wall, and all lines and point angles, internal and external, were rounded, and the cavosurface margins were 90 degrees. The palatal cusp was reduced by 2 mm and bevelled in an angle of 45 degrees along with the longitudinal axis of the premolar with a depth of 2 mm. The palatal margin was in the form of a rounded shoulder with a depth of 1 mm and placed 2 mm away from the tip of the palatal cusp. The axial wall of the resulting shoulder was reduced by 1.5 mm and was occlusally convergent by 10 degrees and had the same path of draw as the main portion of the preparation (Fig.1).

Immediate dentin sealing

The IDS technique was applied upon completion of the preparation of the first group and before temporisation and making the final impression. Acid etching of the freshly cut dentin was performed for 15 seconds by phosphoric acid (H_3PO_4) (UNI-ETCH® [32%], BISCO, Inc., IL, USA) with the extension of the application 1 mm towards enamel margins. Then, it was rinsed thoroughly and dried, leaving the preparation visibly moist, and a coat of dual-cured universal dental adhesive system (ALL-BOND 3®, BISCO, Inc., IL, USA) was applied to the preparation and agitated for total of 10 seconds and air-dried. It was then light-cured for 10 seconds (LEDition, Ivoclar Vivadent AG, Schaan, Liechtenstein). After that, a thin coat of light-cured low viscosity resin (ALL-BOND 3® RESIN, BISCO, Inc.) was applied to the preparation and light-cured for 10 seconds. Subsequently, a thin layer of flowable composite resin (Te-Econom Flow, Ivoclar Vivadent AG) was applied and light-cured for 20 seconds, the unpolymerised superficial oxygen-inhibited layer (OIL) was wiped using an alcohol-moistened cotton pellet. Light polymerisation was repeated for 20 seconds after covering the sealed surface with glycerine jelly ("air blocking"). The preparation was finally redefined, and the enamel margins were re-bevelled. They were finished and polished using fine diamond burs and rubber polishing tips.

Impression-making

The impression was immediately made in the DDS group after the completion of preparation, whereas in the IDS group it was made after the completion of the IDS technique. Twenty impressions were made of the 20 prepared premolars using perforated custom trays, by following the putty-wash one-step

technique, using a condensation silicone putty and light body (zetaplus/oranwash L/indurent gel, Zhermack SpA, Italy).

Temporary restoration

A coat of provisional separating material (PRO-V COAT®, BISCO, Inc., IL, USA) was applied to the entire preparation and air-dried for 15 seconds. The temporary restoration was created using a light-cured provisional packable composite (PRO-V FILL®, BISCO, Inc.), which was light-cured for 10 seconds. Then, a layer of light-cured low viscosity liquid polish (BisCover™ LV, BISCO, Inc.) was applied over the entire surface of the provisional restoration and light-cured for 30 seconds.

The premolars were stored in an atmosphere of 100% relative humidity at a temperature of 37 °C, where the sample was placed in dry heat sterilisation unit (TS TAU STERIL 2000 Automatic, Fino Mornasco, Italy) to match the oral environment conditions for a period of 14 days.

Laboratory procedures

The impressions were cast using type IV dental stone (ISO 6873, Type 4; Die Stone Premium, South Korea). The gypsum master cast scanning was performed (SMART [Big], Open Technologies Optical 3D Scanner, Italy) and the type and material of the restoration were chosen by the Exocad DentalCAD software (Exocad GmbH, Germany). The thickness of the cement was assigned at 20 µm, along with a distance of 1 mm from the margins of the preparation. The wax patterns of the onlays were designed in a fully anatomical form and milled using a wax molding disc (Shenzhen Vasden Bioceramics Co., Ltd., China) by an in-lab CAD/CAM system (Roland DWX-51D, Roland DGA Corporation, CA, USA). These patterns were invested in the phosphate-bonded investment (Maruvest Speed, Megadental GmbH, Germany). The ceramic onlays were fabricated by heat-pressed technique using lithium disilicate glass-ceramic in HO 1 color according to the manufacturer's instructions (IPS e.max Press, Ivoclar Vivadent AG, Schaan, Liechtenstein), after that the margins were stained using khaki stain.

Cementation

The ceramic onlays were placed into the preparations after removing the temporary restorations and cleaning the preparations, where their stability and the adaptation of their margins were tested using the probe. Their internal fit was checked using a condensation silicone wash (Speedex Light Body/Universal Activator, Coltène/Whaledent AG, Altstätten, Switzerland). The ceramic onlay was disinfected with ethyl alcohol. Then, the internal surface was cleaned with phosphoric acid (H_3PO_4)

(ETCH-37™ [37%], BISCO, Inc., IL, USA) for 30 seconds. 9% hydrofluoric acid was applied for 20 seconds (Porcelain Etch, Ultradent Products, Inc., UT, USA). It was put in an ultrasonic cleaning device (Clean-02; Ultrasonic cleaner, Runyes Medical Instrument Co., Ltd., Ningbo, China) and dried using a hot-air dryer. After that, 2 layers of a silane solution (Silane, Ultradent Products, Inc., UT, USA) were applied, and they were left for 60 seconds. The restoration was heated by applying a warm air current for 30 seconds, then a coat of universal dental adhesive system (All-Bond 3®) was applied and gently air-dried without light-curing. The premolars were cleaned with a brush and a polishing paste containing fluoride-free pumice powder. For the abutment in an IDS group a sandblaster (CoJet™ Prep, 3M ESPE AG, Seefeld, Germany) with a silica-coated particle size of 30 µm (CoJet™ Sand; CoJet™ System, 3M ESPE AG) under a pressure of 30 psi from a distance of 10 mm and at a 45° angle was used for 3 seconds. Then phosphoric acid (UNI-ETCH® [32%]) was applied for 15 seconds to the preparation surfaces for etching the enamel margins and cleaning the conditioned sealed surfaces. A layer of silane solution (ESPE™ Sil; CoJet™ System, 3M ESPE AG) was applied to the entire conditioned sealed surfaces and gently air-dried. Then, 2 coats of dual-cured dental adhesive system (All-Bond 3®) were applied to the entire preparation then gently air-dried, and left without light-curing.

As for the teeth in the DDS group, phosphoric acid (UNI-ETCH® [32%]) was applied to the entire preparation for 15 seconds with rinsing and drying, and a coat of dental adhesive system (All-Bond 3®) was applied, gently air-dried, and light-cured for 10 seconds.

The onlays were cemented with dual-cure conventional resin cement (Variolink N, Ivoclar Vivadent AG, Schaan, Liechtenstein). Sonic tips (SF1981/SF12; Komet Dental, Brasseler, Lemgo, Germany) mounted on a sonic hand-piece (AS2000 M4; NSK, Nakanishi, Inc., Tochigi, Japan) were used to apply a pressure of 1.5 N for 4 seconds to ensure the gentle and precise positioning of the onlays. Light-curing was done for 5 seconds. Then, the margins were cleaned, and the curing was carried out for 40 seconds from all sides. The margins were finished with rubber flame-shaped tips, cones, and discs. Figure 2 shows 2 ceramic onlays from the 2 groups after final cementation on the teeth.

Thermal cycles

All restored teeth were subjected to thermocycling at 500 cycles in water baths between 5 °C and 55 °C and in 15 seconds at each temperature.

Fracture load measurement

The fracture load of the specimens was determined using a universal testing machine (Testometric M350-10KN, The Testometric Company, Ltd., Rochdale, UK) where the compressive loads were applied in a perpendicular way to the center of the occlusal surface of the ceramic onlays with a 6-mm stainless steel round-ended rod that contacted the buccal and palatal triangular ridges and along the axis of the restored teeth at a 1-mm/min crosshead speed until fracture (Fig. 3). The maximum compressive load (N) required for causing fracture was recorded for each specimen. The failure types were examined under a stereomicroscope at 10× magnification, and the failure mode was categorised as follows; mode I: fracture of the restoration only, mode II: fracture of the restoration with a small



Fig. 2 The final ceramic onlays. On the left: IDS technique. On the right: DDS technique

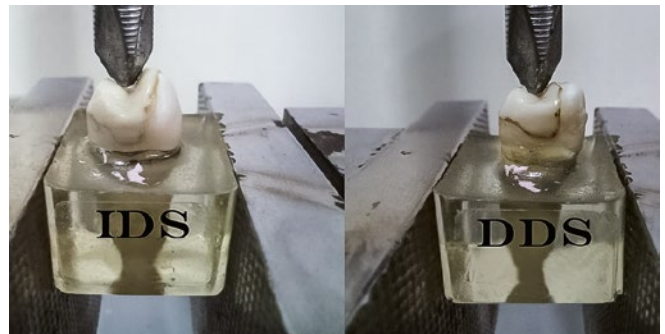


Fig. 3 The force was applied on the occlusal surface using Testometric M350-10KN (The Testometric Company Ltd.).

portion of the tooth, mode III: fracture of the restoration with more than half of the tooth, and mode IV: fracture involving the root.

Statistical study

The data was analysed statistically using IBM SPSS Statistics v.25 software (IBM Corp., Chicago, IL, USA). The Shapiro-Wilk test was used to test distribution of the data. The mean and standard deviation were calculated for each group. Then, an independent-samples t-test was run to determine if there were significant differences in fracture strength between the 2 groups. The selected level of statistical significance was $p < 0.05$.

Results

Data obtained for the fracture load for each group were normally distributed as assessed by Shapiro-Wilk test ($p > 0.05$). Table I shows the descriptive statistics of the fracture strength (N) in the 2 groups, where the highest mean fracture strength was recorded at 1785 N.

Tab. I The descriptive data for fracture strength values (N) of test groups

Group studied	IDS	DDS
Number	10	10
Mean	1.335	931
Standard deviation	335	274
Standard error of the mean	106	87
Minimum	723	420
Maximum	1.785	1.286

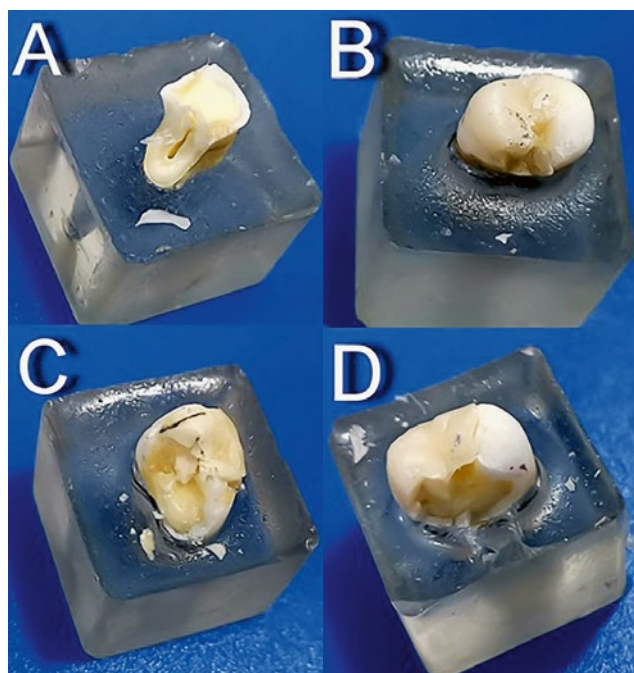


Fig. 4 Some failure modes happened after fracture test: A) mode IV, B) mode I, C) mode III, D) mode II

Tab. II Results of paired comparisons using t-student test

T value	2.95
Degrees of freedom	18
Difference of the two means	394
Standard error of difference	137
Significance level	0.0085*
* statistically significant: p value < 0.05	

Tab. III Fracture modes of restored specimens

Mode of failure	IDS Group	DDS Group
I	(20%)	(20%)
II	(50%)	(40%)
III	(10%)	(10%)
IV	(20%)	(30%)
Mode I; fracture of the restoration, mode II; fracture of the restoration and small amount of the tooth, mode III; more than half of the tooth, mode IV; root fracture.		

The t-test revealed that there were statistically significant differences in the fracture strength between the 2 groups, where the mean fracture strength in the IDS group was (1335 ± 335 N) higher than compared to the delayed DDS group (931 ± 274 N), at a significance level of 95% and $p < 0.05$ (Tab. II).

Table III shows the mode of failure within each group. The restoration fracture with a small portion of the tooth (mode II) was the most common mode of failure in both groups, while root fracture (mode IV) appeared in 30% of the cases in the DDS group and in 20% of the cases in the IDS group. Figure 4 shows some failure modes that occurred.

Discussion

To guarantee good bonding of indirect adhesive restorations to dentin, some researchers recommended the application of a dentin bonding system to the freshly cut dentin immediately after tooth preparation and before making the impression. This is called immediate dentin sealing (IDS). This technique provided many advantages, especially in relation to improving the bond strength (MAGNE ET AL. 2005; OKUDA ET AL. 2007; MAGNE 2014). Due to the fact that fracture is the most common failure mode (MORIMOTO ET AL. 2016), the aim of this study has emerged.

In the current benchtop study, the premolars were embedded in acrylic blocks to facilitate the various working procedures, especially when determining the fracture load of the specimens using later a universal testing machine, owing to the elastic modulus of acrylic close to the alveolar bone (SCHERRER & DE RIJK 1993). In the IDS group, the HEMA-free, hydrophobic, filled bonding resin (All-Bond 3[®]) was applied to the entire sealed dentin surface to obtain a homogeneous resin layer that has the ability to reduce microleakage, make the bonding layer less prone to water sorption, protect the hybrid layer during the temporisation phase and prevent the possibility exposure of mineralised dentin during pre-cementation cleaning of the tooth preparation (STAVRIDAKIS ET AL. 2005). A thin layer of flow-able composite resin (Te-Econom Flow) was also applied to the entire IDS surface as a stress-absorbing layer with a low coefficient of elasticity to protect the dentin-resin adhesive interface from the fatigue caused by stresses, especially the overlaying resin cement shrinkage and occlusal forces (BAROUDI & RODRIGUES 2015). The enamel margins were re-prepared just before final impression to remove excess adhesive resin, to provide ideal taper for onlays, and to make direct bonding of the restoration to the enamel.

As for the temporary restoration, a water-soluble separating agent (PRO-V COAT[®]) was used to prohibit bonding of the provisional to the adhesive interface or tooth structure, protect the dentin surface from contamination, and clean up effortlessly without any residue (MAGNE 2005).

The wax patterns were milled by computer-aided design and computer-aided manufacturing (CAD/CAM) technique, where the IDS and its effectiveness were verified with CAD/CAM restorations. It was found that there is an improvement of the bond strength of ceramic and composite onlay restorations fabricated with this technique (ISHII ET AL. 2017; MURATA ET AL. 2018).

In this study, the mean fracture strength in the DDS group and the IDS group were 931 N and 1335 N, respectively. The force required to fracture ceramic onlays was higher than the value of human masticatory forces. The average masticatory forces do not exceed 270 N (NAEIJ & LOON 1998), while the fracture strength in this study ranged between the lowest value (420 N) and the highest value (1785 N). Thus, the average human masticatory force was under this range. According to BAKKE (2006), the value of bite forces in the premolar's region ranges between 200 to 300 N. In any case, there is no consensus in the dental literature on the average values of masticatory forces, bearing in mind that the force is clinically distributed over more than one dental component which reduces the load on a single tooth.

The strength of glass-ceramic restorative materials depends on the bond strength of resin cement to the internal surface of the restoration and to the various dental tissues of enamel and dentin (PEUMANS ET AL. 2000). The mean fracture strength in this study was close to that mentioned in a similar study (SPOHR ET AL. 2013), where the mean fracture load of the IPS impress 2 ce-

ramic crowns in the IDS and the DDS group was 1300 ± 230 N and 1.001 ± 186 N, respectively. Also YAZIGI ET AL. (2017) concluded that the mean fracture load values of thin CAD/CAM-fabricated occlusal glass-ceramic veneers were 1.275 N without IDS and 1.804 N with IDS.

On the other hand, the mean fracture strength of molars restored with lithium disilicate overlays was 2.011 N in the IDS group and 1.837 N in delayed sealing (HOFSTEENGE ET AL. 2020). The difference might be attributed to the difference nature of the samples which are bulkier and the lack of marginal ridge and specific morphology of the premolars.

The IDS group showed better fracture strength than the DDS group, as the resin materials were cured before impression, leading to a formed thickness that had a positive effect on the fracture strength values in the IDS group. The resin materials were applied to seal the dentin, smoothen the internal preparation surfaces, and create rounded internal line angles. These are required because of the shapes of the burs used to mill the wax molding disc or ceramic block and to achieve excellent cavity wall adaptation of the pressed and milled ceramic restorations (HOPP & LAND 2013). Following the IDS technique appears to protect the dentin-resin adhesive interface during pre-cementation cleaning of the tooth preparation after removing of temporary restoration and when using the intraoral micro-blasting device before final cementation. Furthermore, the dentin-resin adhesive interface is protected from stresses caused by the polymerisation shrinkage of resin cement during final cementation (STAVRIDAKIS ET AL. 2005). Furthermore, the use of a low-modulus flowable composite resin material acts as a stress-relieving layer.

The reason for the higher fracture load in the IDS group could also be attributed to the fact that the IDS with the adhesive system, filled resin, and low-viscosity microfilmed resin has significantly improved the bond strength of the ceramic restorations bonded to dentin using the resin cement (OKUDA ET AL. 2007; SULTANA ET AL. 2007).

YAZIGI ET AL. (2017) proved that a higher fracture strength of thin CAD/CAM-fabricated occlusal lithium disilicate glass-ceramic veneers can be obtained when using IDS, regardless of the bonding technique used, whether it was total or selective etching protocol. EL-DAMANHOURY & GAINANTZOPOULOU (2016) showed that the IDS did not improve the fracture strength of CAD/CAM-fabricated endocrowns when using the conventional feldspathic ceramic (Vita Mark II, Vita Zahnfabrik, Bad Säckingen, Germany), where IDS had a negative influence on the flexure resistance of the restored teeth, with a significant decrease in the obtained values. The reason for that was explained by the presence of optical powder residues.

The failure mode in this study varied from the fracture of the restoration only to the fracture of the root. Root fracture can occur when the loading is strong enough to exceed the borne limits of the tooth (STAPPERT ET AL. 2005; SCHMIDT ET AL. 2011), especially with the roots that are thinner. Root fracture was seen in 20% of the cases in the IDS group, while when not applying the IDS, the fracture of the roots reached to 30%. The force required to fracture the restoration is much higher than the common masticatory forces in oral cavity. Therefore, the destructive fracture mode is not seen in clinical studies of onlays (BEIER ET AL. 2012). Most of failure modes in the 2 groups in this research were represented by the fracture of the restoration with a small part of the tooth, despite the bonding failure mode of the restoration with the tooth was not seen that can be explained by the

high bonding strengths of a glass-ceramic to the dental tissues. In these cases, the adhesion was done in a dry, contamination-free medium. Consequently, a cohesive failure happened in the restoration or in the tooth itself. This is consistent with many previous studies (VAN DEN BREEMER ET AL. 2017; HOFSTEENGE ET AL. 2020). However, in other previous studies, there were other failure modes, such as the adhesive failure mode between the restoration and the tooth, especially in laminate veneers (GRESNIGT ET AL. 2016).

Some limitations of this study are represented by the fact that it was performed in a dry medium and under static conditions. Consequently, it was not completely similar to wet clinical conditions. In addition to that, the intraoral forces vary in quantity, application, speed, and direction. However, the forces in this experiment were increasingly applied until fracture occurred. Therefore, this may not be the same as for oral conditions. However, the aim of the fracture strength studies is to determine the structural integrity of the restored tooth and restoration. Therefore, these types of studies are only considered as a tool for making a preliminary comparison in order to assess the relative effectiveness of examined technique.

Conclusions

Within the limitations of this in-vitro study, the following can be concluded:

1. The onlays in both techniques were strong enough to withstand physiological masticatory forces.
2. Dentin sealing affected the fracture strength of ceramic onlays; the onlays bonded using immediate dentin sealing technique showed higher fracture strength than those bonded using delayed dentin sealing.
3. Most of the failure modes in both groups were restoration fracture with a small portion of the tooth.

Bearing in mind the limitations of this study, it can be recommended to use the IDS technique in clinics by applying the dentin bonding system and low viscosity resin materials to the freshly cut dentin immediately after tooth preparation and before making the final impression.

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Conflict of interest

The authors declare that there are no conflicts of interest related to this study.

Zusammenfassung

Einleitung

Um die Adhäsion geklebter Onlays ans Dentin zu verbessern, wurde die sogenannte Immediate-Dentin-Sealing-(IDS-)Technik propagiert. Eine hohe Frakturresistenz solcher Restaurationen wird als Ziel angegeben. Diese Studie untersuchte die Frakturresistenz adhäsiver Onlays nach IDS und nach konventionellem Vorgehen (delayed dentin sealing, DDS).

Material und Methoden

Zwanzig extrahierte obere Prämolaren wurden für die palatinale Höckerüberkuppelung (MODP) präpariert. Die Zähne wurden in 2 Gruppen von jeweils n = 10 stratifiziert eingeteilt: IDS und

DDS. Das Dentin in der IDS-Gruppe wurde sofort nach Präparation mittels eines Bonding-Systems (All-Bond 3) und eines fließfähigen Kompositmaterials (Te-Econom Flow) versiegelt. In beiden Gruppen wurden Abdrücke genommen und die Kavitäten mit einem Provisoriumsmaterial (Pro-V Coat, Pro-V Fill und BisCover LV) verschlossen. Die Zähne wurden dann für 2 Wochen bei 37 °C aufbewahrt. Danach wurden die aus Lithium-Silikat-Glaskeramik (IPS e.max Press) gefertigten Onlays mit Kompositzement (Variolink N) befestigt. Nach der definitiven Versorgung wurden die Zähne thermozykliert (500 Zyklen zwischen 5 °C und 55 °C). Danach wurde die Frakturresistenz der restaurierten Zähne in einer universellen Testmaschine (Testometric M350-10KN) gemessen. Der «student's t-test» wurde verwendet, um die Mittelwerte zwischen den beiden Gruppen zu vergleichen ($\alpha = 0,05$). Zudem wurde der Frakturmodus mittels Stereomikroskop untersucht.

Resultate

Die Frakturresistenz differierte signifikant zwischen den beiden Gruppen ($p < 0,05$). Der Mittelwert (\pm Standardabweichung) in der IDS-Gruppe war 1335 \pm 335 N und somit signifikant höher als derjenige in der DDS-Gruppe (931 \pm 274 N). Der tiefste gemessene Wert (420 N) war in der DDS-Gruppe, der höchste in der IDS-Gruppe (1785 N). Eine Fraktur der Restauration zusammen mit einem kleinen Zahnfragment war der häufigste Frakturmodus.

Diskussion

Unter den hier beschriebenen Studienbedingungen gab es eine signifikante Verbesserung der Frakturresistenz von Teil-Onlays, wenn die Zähne mittels IDS behandelt wurden. Es muss jedoch einschränkend gesagt werden, dass dies eine In-vitro-Studie war und die Frakturresistenz in beiden Gruppen grösser war als die normale Kaukraft.

Résumé

Introduction

Afin d'améliorer l'adhésion à la dentine des onlays collés, la technique dite «*immediate dentin sealing*» (IDS) a été préconisée. L'objectif déclaré de ce type de restauration est d'obtenir une résistance élevée à la fracture. Cette étude a investigué la résistance à la fracture d'onlays collés selon la procédure IDS

comparativement à la procédure conventionnelle («*delayed dentin sealing*», DDS).

Matériel et méthodes

Vingt prémolaires supérieures extraites ont été préparées pour le recouvrement des cuspides palatines (MODP). Les dents ont été réparties en deux groupes de $n = 10$ chacun: IDS et DDS. Dans le groupe IDS, la dentine a été scellée immédiatement après la préparation à l'aide d'un système de collage (All-Bond 3) et d'un matériau composite fluide (Te-Econom Flow). Dans les deux groupes, des empreintes ont été prises et les cavités ont été obturées avec un matériau de restauration provisoire (Pro-V Coat, Pro-V Fill et BisCover LV). Les dents ont ensuite été conservées à 37 °C pendant deux semaines. Puis les onlays fabriqués en vitrocéramique au silicate de lithium (IPS e.max Press) ont été scellés avec un ciment composite (Variolink N). Après la restauration définitive, les dents ont été thermocyclées (500 cycles entre 5 °C et 55 °C). Ensuite, la résistance à la fracture des dents restaurées a été mesurée au moyen d'une machine de test universelle (Testometric M350-10KN). Le «student's t-test» a été utilisé pour comparer les valeurs moyennes des deux groupes ($\alpha = 0,05$). De plus, le mode de fracture a été examiné au moyen d'un stéréomicroscope.

Résultats

La résistance à la fracture a différé significativement entre les deux groupes ($p < 0,05$). La valeur moyenne (\pm écart type) dans le groupe IDS était de 1335 \pm 335 N, c'est-à-dire significativement plus élevée que celle du groupe DDS (931 \pm 274 N). La valeur la plus basse (420 N) a été enregistrée dans le groupe DDS, et la plus élevée, dans le groupe IDS (1785 N). Le mode de fracture le plus fréquent était une fracture de la restauration accompagnée par un petit fragment de dent.

Discussion

Dans les conditions d'étude décrites ci-dessus, une amélioration significative de la résistance à la fracture des onlays partiels a été mise en évidence lorsque les dents avaient été traitées par IDS. Il convient toutefois de nuancer ces résultats en rappelant qu'il s'agissait d'une étude in vitro, et que dans les deux groupes, la résistance à la fracture était plus importante que la force masticatoire normale.

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