Effect of Preparation Design on Retention of PEEK and Lithium Disilicate Occlusal Veneer

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Abstract:

Objectives: This study's objective was to ascertain how preparation design affected the preservation of occlusal veneers made of PEEK and lithium disilicate.

Materials and Methods: A total of 32 mandibular molars mounted in epoxy resin models along their long axes on the dental surveyor. CAD/CAM blocks teeth were divided into two test groups (n=16) to fabricate the occlusal veneers of 1.0 mm, group (1): PEEK, and group (2): IPS e.max CAD. The preparation design for occlusal veneer was then used to divide each group into two equal subgroups (n=8), where subgroup (A) represented the minimally invasive occlusal veneer preparation resembling advanced occlusal erosion. Occlusal veneer preparation with a marginal chamfer was represented by subgroup (B). After cementation, the Specimens were put through 5000 cycles of cyclic fatigue loading, which is equal to 5 years of clinical service. Using a universal testing machine, the retention values for all occlusal veneers were determined.

Results: IPS E.max material had higher significant mean retentive values when compared to PEEK material. Also, the planner finishing had a higher significant mean retention value when compared with the chamfer finishing line design for IPS E.max material, however, no statistically significant difference when using PEEK.

Conclusion: Compared to PEEK occlusal veneers, lithium disilicate occlusal veneers offer better retention. Furthermore, occlusal veneers with planner finishing lines exhibited offer better retention than chamfer finishing lines.

Keywords: Lithium disilicate, Occlusal veneer, Preparation design, PEEK, Retention.

Introduction

The occlusal surfaces of the molars and premolars experience progressive dental wear that is difficult to clinically identify in its early stages and is typically discovered when rehabilitation is needed. [1, 2]. However, for a number of years, restorative dentistry has placed little emphasis on tooth wear. Size and extent of the defect may have an impact on how severe erosive lesions are managed [3].

To maintain such dental structures, minimally intrusive methods are strongly advised. This has given rise to creative methods for offering minimally invasive biomimetic dentistry and restoring such erosive defects by employing indirect composite restoration, occlusal veneers, or partial crowns. [4]. According to a biomimetic viewpoint, preserving the delicate balance between biological, mechanical, and aesthetic variables depends on the preservation of tooth structure, but over time, more invasive methods like full-coverage crowns may degrade the restored teeth's functionality and aesthetics [5, 6].

When compared to full coverage crowns, partial coverage preparations such as posterior occlusal veneers remove the least amount of tooth structure [6, 7]. Posterior occlusal veneers are recommended if wear has caused the occlusal enamel's thickness to decrease. Their selection as an enamel replacement was influenced by the availability of more modern, high-strength cosmetic materials in the dental office, such as Polyetheretherketone (PEEK) and lithium disilicate glass ceramics [8-10]. Compared to resins and metals used in dentistry, PEEK is more aesthetically pleasing, stable, biocompatible, lighter, and has a strong resistance to discoloration [10, 11].

Ceramics made of lithium disilicate have the best mechanical qualities. This could be attributed to their interlocking microstructure and the zirconia crystals that are embedded in the glassy matrix and have the shape of needles [12]. Due to their great fatigue resistance, recently improved mechanical and physical qualities of the machinable hybrid materials have made it possible for them to replace glass ceramics, particularly when thin restorations are subjected to strong occlusal stresses [12, 13].

The occlusal veneer materials' clinical performance is mostly dependent on their strength, thickness, and ability to attach successfully to underlying tooth tissues. In addition, one of the most crucial elements for the survival of restorations is the adaptation of the restoration margin [9, 14]. As a result, the purpose of this study was to assess the retention of occlusal veneer restorations in relation to the kind of restorative material used and the preparation strategy.

Materials and Methods:

A power assessment of specimen size determined that a minimum of 8 specimens per group were needed to detect a significant difference between groups based on the earlier work by Valenzuela et al., [15]. Calculations were made with a power of (50%) and a 95% level of significance for the effect size (df=13.55).

32 newly extracted mandibular molars with equivalent mesiodistal and buccolingual diameters that were sound, unrestored, and free of cavities or fractures were collected from the Department of Oral Surgery Outpatient Clinic at Al-Azhar University for periodontal reasons. The teeth were scaled and cleaned to remove tissue tags, and calculus using a hand instrument and then polished with pumice and a rubber cap to remove stains after that the teeth were disinfected in a 0.1% Chloramine T solution for one week. Then, the teeth were stored in a bottle of distilled water at room temperature to avoid dehydration for a period that did not exceed 2 weeks [4, 15].

Teeth were randomly assigned equally to two test groups (n=16) and utilised to create occlusal veneers of 1.0 mm thickness in accordance with the CAD/CAM block materials: group (1): PEEK, and group (2): IPS e.max CAD. The preparation design for occlusal veneer was then used to divide each group into two equal subgroups (n=8), with subgroup (A) representing the minimum invasive occlusal veneer preparation matching advanced occlusal erosion. The occlusal veneer preparation with a marginal chamfer is represented by subgroup (B).

Tooth preparation:

All teeth were mounted in epoxy resin models (Polypoxy 700, polymer, chemical industries for construction Co., CIC, Egypt) along their long axes at 2 to 3 mm above their cementoenamel junction (CEJ) and then mounted on the dental surveyor. The tooth preparation was done with a low-speed handpiece with a high-speed adaptor for burs mounted on the dental surveyor [16].

For subgroup A; The usual depth of the occlusal tooth reduction was 1 mm. A coarse diamond cylindrical bur with a 1 mm diameter (835 KRM 314008, Komet, Lemgo, Germany) was used to create four depth grooves in the occlusal surface of each tooth, adhering to the tooth's architecture. The enamel parts in between these depth grooves were then removed using a round-ended cylindrical diamond bur (836 KR

314 018, Komet) to join them. About 5.0 mm were kept between the buccal and palatal margins and the CEJ. Finishing the occlusal preparation was a fine-grit diamond bur (8846 KR 314 016, Komet). After that, abrasive rubber tips were used to polish the prepared surfaces (9608 314 030, Komet). As much as feasible, the cuspal inclination was maintained [4, 6]. (Figure 1)

For subgroup B; The top of the axial wall was next prepped for a chamfer finish line on each tooth specimen using a tapered bur with a noncutting guide pin at its tip, and the process was completed with a fine-grit bur. The cuspal inclination was maintained as consistently as feasible when polishing the previously prepared surfaces using abrasive rubber tips [4]. (Figure 2)

In order to standardize the preparation, polyvinyl siloxane (PVS) imprint and cutting bur in the same location and by the same operator, all preparations were carried out at the same height and reduction [17].

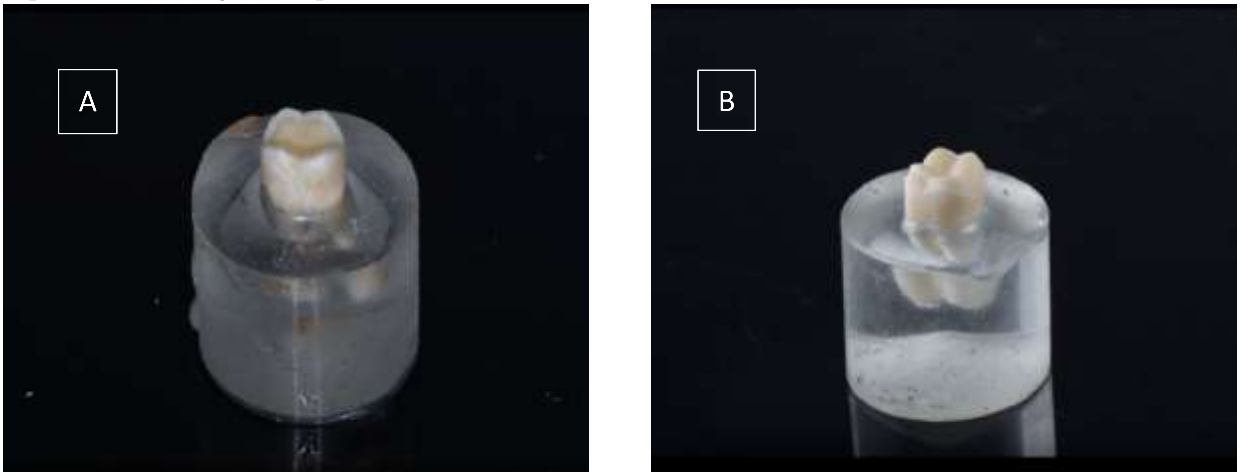

Figure 1: Photograph showed; A) planner occlusal preparation; B) occlusal preparation with a chamfer finish line.

Following the manufacturer's recommendations, the exposed dentin surface of each produced tooth was immediately sealed once tooth preparation processes were completed. Using a gentle brushing motion, the glue (Adper Easy Bond Self-Etch Adhesive, 3M ESPE, St. Paul, Minnesota) was applied to the exposed dentine for 20 seconds. After gently air-drying for 5 seconds, the adhesive was light-cured for 10 seconds at a power of 1200 m.W/cm^2 using an LED light-curing unit (Bluephase, Ivoclar Vivadent, USA). Before the restorative treatments, all of the prepared and sealed specimens were kept in a normal saline solution for 24 hours at 37°C [4].

Occlusal veneers manufacturing:

Each preparation in each tooth was scanned using an intraoral scanner (MEDIT, Germany). Then, each occlusal veneer was designed and milled from the desired milling blocks to rebuild its corresponding tooth as follows; the scanned image of each prepared tooth appeared on the computer screen. The obtained image of each scanned preparation was then imported into CAD software for the design of the occlusal veneer. Using CAD/CAM system software (programmed P500, Ivoclar, Vivadent, Schann, Lieichtein) for planning the restoration, occlusal veneers were built using PEEK and E. max CAD/CAM blocks. Each occlusal veneer was calibrated to have a cement thickness of 60 m and a homogeneous 1-mm thickness across the whole occlusal surface[4,6]. An interior relief spacer of 60 microns was employed in all designs to ensure uniformity. Two wings were included into the occlusal veneer design of each material for the pull-out (retention) test [17].

After the milling processes, the E.max CAD occlusal veneers were crystallized in a programmable furnace at 850^{o}C for 30 minutes. For PEEK, the occlusal veneers were polished and smoothed using the prescribed polishing set per the manufacturer's instructions, without any sintering or crystallization procedures. All milled veneers were rigorously checked for any fractures or defects once the milling operations were completed [4, 6].

Cementation protocol:

Before the cementation procedures began, each veneer was checked to ensure it was properly seated on its corresponding tooth. The inside surface of each occlusal veneer was washed with alcohol before being air-abraded, cleaned, and dried with oil-free air using the manufacturer's recommended 110m of aluminum oxide particles at 1.8 bar of pressure (Cojet System, 3M, St. Paul, Minnesota) [18, 19].

The fitting surfaces of all occlusal veneers were cleaned for three minutes in an ultrasonic cleaner before being etched for 20 seconds with 5% hydrofluoric acid (IPs Ceramic etchant gel, Ivoclar, Vivadent) prior to cementing E. Max. After that, a silane coupling agent was used (Variolink S bond, Ivoclar, Vivadent), which was applied, dried, and then air distributed to create a thin layer [4, 6].

The sealed dentin surfaces were air abraded using an intra-oral air abrasion device using 40 m aluminum oxide particles at 30 bars of pressure until the surfaces became dull prior to the cementation operations. According to the manufacturer's instructions, the surfaces were then washed with alcohol and dried with pressured air that was oil-free. Each prepared tooth was then completely washed with water spray for 20 seconds following cleaning processes, etched for 30 seconds with 37% phosphoric acid (Etchant3M ESPE, St. Paul, Germany), and dried with oil-free air. In accordance with the manufacturer's recommendations for each type of occlusal veneer, the produced veneers' bonding surface was then immediately coated with newly made self-adhesive, dual-cure resin cement [4, 6, 16].

The occlusal veneers were held in position during the main cement setting with a static load of 5 kg weight to achieve consistent seating pressure. After being light-cured for two seconds, the extra cement was removed using an explorer while it was still in the gel stage. Each specimen was then light-polymerized using an LED light-curing equipment for 20 seconds on each side at a distance of 1 mm. All produced specimens were kept in distilled water at 37°C after restoration bonding until testing [4, 6, 16].

Thermocycling and testing procedures:

Before testing, each specimen underwent 5000 cycles of thermal cycling in a thermocycling device (JULABO, FT200 immersion cooler, USA) between 5°C and 55°C with a dwell period of 30 seconds [20].

Two holders were fastened to the previously prepared wings of each occlusal veneer to create a homogeneous distribution of tension for the retention (pull-out) test. The occlusal veneers were then tested using a universal testing machine* with a crosshead speed of 0.5 mm/min till failure. The software automatically drew the retention force in Newton (N), and each specimen's stress of removal was computed and then shown in megapascal (MPa) [16, 17, 21].

Statistical analysis:

SPSS® Statistics Version 20 was used. To compare the two groups, a t-test was employed for quantitative variables that had a normally distributed distribution. To compare more than two groups using normally distributed quantitative variables, the F-test (ANOVA) was used. The significance threshold was established as less than 0.05.

Results:

CAD/CAM restorative materials utilized in this study, regardless of the preparation design, had a statistically significant effect on mean retentive values. The results revealed that E.max had higher significant mean retentive values when compared to PEEK. Whereas the preparation design, regardless of the material utilized, had a statistically significant effect on mean retentive values. Where the planner finishing had the higher significant mean retention value when compared with the chamfer finishing line design. (Table 1)

No statistically significant difference between the mean retentive values for the two preparation designs using. But according to IPS E.max data, there was a statistically significant difference between the mean retentive values for the two preparation designs following thermal aging, with the planner finishing line displaying the greater significant retentive mean. (Table 2)

Table (1): Comparison of the retention results of occlusal veneers with planner finishing line of PEEK vs E.max

Variables	PEEK		E.max		p-value
	Planner	Chamfer	Planner	Chamfer	
Mean± SD	108.17±1.75[A]	74.86±15.03[A]	443.23±45.97[B]	242.96±50.67[C]	<0.0001*

*; Sig. at p<0.05. NS; Non-Significant. Different uppercase letters mean statistically significant.

Table (2): Comparison of the retention results of occlusal veneers with a planner and chamfer finishing line of PEEK vs E.max.

Variables	Planner (Mean± SD)	Chamfer (Mean± SD)	p-value
PEEK	108.17±51.51	74.86±15.03	0.101 ns
E.max	443.23±45.97	242.96±50.67	<0.0001*
p-value	<0.0001*	<0.0001*	

*; Sig. at p<0.05. NS; Non-Significant

Discussion:

The retention needs to be improved in situations with short abutments, such as occlusal veneers, and peculiar dislodging forces in order to produce more predictable results [17]. In order to maximize their retention force and mimic clinical settings, resin cement was used in this investigation with PEEK and E.max occlusal veneers. The occlusal veneer was selected to be tested in the present study because, in contrast to conventional overlays or full-coverage crowns, ultrathin occlusal veneers have been promoted as a conservative approach to "reenamelize" the occlusal surface [22]. The occlusal veneer is one of the most recent conservative treatment choices. When the occlusal enamel is thinner than normal and the underlying dentin is visible at the occlusal surface, occlusal veneers are recommended [6].

This study looked at the retention of two occlusal veneer preparation designs (planner and chamfer) made of two distinct ceramic materials. This is because, for teeth where a significant amount of dental tissue has already been lost due to wear and erosion, minimally invasive designs or the "no-preparation" approach with an infinite completion line have many proponents, as further tooth preparation in these circumstances may be detrimental. However, it is possible to hypothesize that a shoulder finish line provides more support than an indefinite finish line in the conventional design [6].

Moreover, both PEEK and e.max were selected as occlusal veneers in this current investigation because thinner designs are possible thanks to the inherent strength of materials such as lithium disilicate-reinforced glass ceramics and high-performance PEEK, as well as rapid dentin sealing [15, 23, 24]. Although milling a fully sintered prefabricated PEEK and E.max blanks to the desired dimension was used in this investigation rather than firing, it is claimed that it has a superior marginal fit because there is no shrinkage involved in the manufacturing process [11, 24].

In this study, the depth groove stone was utilized for standard preparation with 1 mm of cusp reduction and 1 mm of depth of the central fossa to provide suitable thickness for the occlusal veneer restorations [6]. Furthermore, due to its elasticity modulus being close to that of human bone, epoxy resin was employed to embed the roots of the teeth in this current investigation [25].

In this current study, to be as realistic as possible, the occlusal veneers were built on natural molars rather than using die materials [6]. Due to their elasticity modulus, bonding properties, thermal conductivity, and strength being closer to those of clinically relevant human molars, extracted human molars were utilized in the current study [24, 26]. Furthermore, due to the fact that freshly sliced dentin offers the best substrate for bonding in this situation, the immediate dentin sealing protocol was used in the current investigation [4].

According to the recommendation of previous studies for adequate seating 5 kg of weight was pointed parallel to the teeth's longitudinal access over the correspondingly prepared teeth, and the crowns in this investigation were cemented using a specific loading mechanism [4, 24]. Because the internal adaptability and final strength of resin cement can be affected by the seating pressure [17].

All specimens in this present study were subjected to thermal cycling in order to simulate the clinical condition because it was stated that one of the most popular methods for simulating the physiological aging that biomaterials go through in clinical settings is the thermal cycling [6]. In this investigation, the subgroups of the two materials underwent thermocycling for 5000 cycles at a temperature between 5 and 55 ^{o}C with a dwell time of 30 seconds to simulate five years of clinical aging [6, 20].

The study's findings demonstrated that IPS E.max occlusal veneers had statistically significantly greater mean retentive force values than PEEK occlusal veneers. This could be explained by the strong link that lithium silicate ceramics and resin ultimately form, according to numerous writers [25, 27, 28].

Moreover, the results of retention of this present study revealed that the planner finishing line design showed higher mean retentive values in both tested materials (PEEK and IPS E.max) when compared with the chamfer finishing line. This could be attributed to the thinner dimension of the planner finishing line when compared with the chamfer finishing line [6]. These agreed with the results of previous works that demonstrated that thin finish lines produced marginal gaps that were substantially wider than rounded shoulders because they did not allow for a proper internal adaption of the restoration [28, 29].

The results of this study also showed that the E.max occlusal veneers had higher mean statistically retentive values when compared with the PEEK occlusal veneers regardless of the finishing line design. This might be mostly due to the thermal fatigue of PEEK occlusal veneers during thermocycling, which happens when the material deforms mechanically after going through cycles of heating and cooling. Numerous studies have shown that water functions as a plasticizer in a polymer matrix composite structure, which causes the materials to deform [6]. [2,113] Moreover, it was stated that the integrity of bonded surfaces could be harmed by this occurrence, known as osmotic blistering, which could also degrade the cement layer's quality [17].

Moreover, in this investigation, PEEK occlusal veneers had statistically significantly lower mean retention values than E.max occlusal veneers regardless of the design of the finishing line. These outcomes can be attributed to the semi-crystalline structure of PEEK, which has a number of fillers contained in the resin matrix and may cause a bigger marginal gap during production than polycrystalline E.max [24].

Conclusion:

The following conclusions could be drawn however the constraints of the current investigation; Compared to PEEK occlusal veneers, lithium disilicate occlusal veneers offer better retention. Occlusal veneers with planner finishing lines exhibited offer better retention than chamfer finishing lines. The interaction between the different material types and the preparation design had a significant impact on the retention values.

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