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INFLUENCE OF PREPARATION DESIGN ON FRACTURE RESISTANCE OF HYBRID CERAMICS OCCLUSAL VENEER

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ABSTRACT

Objective: To assess the fracture load of lithium silicate occlusal veneers reinforced with zirconia at two thicknesses of 0.3 and 0.6 mm, luted to either dentin or enamel, in vitro.

Materials and methods: Forty human maxillary premolars were randomly distributed into four groups (n = 10): Veneers that are E1-0.3 mm thick, E2-0.6 mm thick, D1-0.3 mm thick, and D2-0.6 mm thick luted to enamel, and dentin, respectively. Following the luting processes, the samples were heated for 5000 thermal cycles (5ºC/55ºC, 1 min dwell period, and 10 second interval) then submerged in distilled water at 37°C for 7 days. A fracture load test was performed on the samples in a universal testing apparatus. A one-way ANOVA test along with a post-hoc analysis test was employed to examine the variation in means among groups. A p-value less than 0.05 was considered significant.

Results: $P < 0.05$ indicated that just the thickness component was significant. Fracture load values: E1 (1436.4N ± 242.1); E2 (1119.1N ± 213.9); D1 (1593.6N ± 285.3); and D2 (1237.6N ±205.5).

KEYWORDS: Zirconia, occlusal veneer, CAD/CAM, ceramic, dentin, enamel, fracture load

INTRODUCTION

Very little intrusive to restore such dental tissue, one of the most advised treatment modalities is biomimetic dentistry(1).

When treating patients whose tooth structure has been severely damaged by tooth wear, the use of traditional methods may involve extensive full mouth rehabilitation. These methods which could have biological ramifications such as the loss of healthy tooth structure. It could also be recognized that extensive preparations are not desirable(2).

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More studies regarding the mechanical and optical characteristics of new CAD/CAM materials must go hand in hand with the growing concern over digital dentistry, as these materials allow for a reduction in the number of clinical sessions and the time required to fabricate dental restorations[3].

Dental ceramics are prone to cyclic mechanical degradation and progressive slow crack growth. It has been documented that the ceramic gradually loses strength at low continuous or cyclic loads, particularly in a humid environment[4]. In an effort to combine the advantageous material properties of zirconia and lithium disilicate ceramic, a zirconia-reinforced lithium silicate ceramic has recently been introduced. Zirconia is added to this new glass ceramic, making up about 10% of its weight. It has been reported that the addition of zirconia particles to the lithium silicate glass matrix strengthens the ceramic structure by preventing cracks. Oxide ceramic and high strength glass ceramic material have favorable color stability, resistance for wear and rate of surviving as a partial coverage restoration[5].

Laboratory studies with various preparation designs are necessary to provide information about stability and longevity because there are currently no established protocols for the preparation of partial coverage restoration, particularly occlusal type[6]. There are still few reports available on indirect ceramic posterior partial coverage restoration preparation guidelines. Most manufacturers advise using minimal ceramic thicknesses of 1.5 to 2 mm[7]. Even with ultra-thin (0.3 mm to 1.0 mm) ceramic thicknesses, some authors have reported ceramic restorations with satisfactory clinical long-term results [8]. i.e. obtained fracture loads comparable to that of healthy teeth[9].

The purpose of this in vitro investigation was to evaluate the fracture load of ZLS CAD occlusal veneers that were luted to either dentin or enamel at thicknesses of 0.3 or 0.6 mm. The study's hypotheses were that the substrate and the thickness of the occlusal veneers would both affect how easily the restorations fractured.

MATERIALS AND METHODS

The Minia University Faculty of Dentistry Ethics Committee (RHDIRB2017122004) authorized the research protocol, which was assigned protocol number 630/2022 at the meeting (89).

In order to have sufficient power to do a statistical test of the null hypothesis—that there is a difference in fracture load between the tested groups—a power analysis was created. By using a 95 percent significance threshold and an alpha level of 0.05, a beta of 0.2 is obtained. For example, if power=80% was computed using the findings of a prior study [10], the expected sample size (n) would be 40 samples in total. G-power 3.1.9.4 was used to calculate the sample size (Heinrich-Heire, Dusseldorf, Germany) Fixed effect, omnibus, and one way ANOVA F tests were performed.

Forty extracted human maxillary first premolars were collected from the Asyut governmental hospital and the outpatient clinic of the Asyut University, Faculty of Dentistry. The teeth were extracted for orthodontic or periodontal reasons. Using an ultrasonic scaler, teeth were freed from soft tissue attachments and kept in distilled water until all the teeth had come in. A thorough inspection was conducted using 2.5X magnifying loupes to make sure there are no cracks, caries, or other flaws. A digital caliper was used to measure the mesiodistal diameter and anatomical crown length. The variation in the teeth's measurements was limited to ±5%. An informed consent form allowing the use of their teeth in the study was filled out by each patient. After the research was completed, the used teeth were given to the university hospital's incinerator.

A dental surveyor (NDI. Ney Dental Inc, Bloomfield Connecticut 06002 USA) was used to place the teeth in the mold parallel to its long axis so that the acrylic resin level was 2 mm below the cervical line.

Based on the two main preparation designs tested, the prepared teeth were then randomly assigned to two main groups (20) samples each:

Group (E) Occlusal veneers preparation within Enamel.

Group (D) Occlusal veneers preparation within Dentin.

Each group was further subdivided into two subgroups (10) samples each according to the thickness of occlusal veneer either 0.3mm sub group (1) or 0.6mm sub group (2).

Before preparing the samples, to standardize the reduction for the teeth putty indices were made before preparation. Addition silicon impression material (Zhermack S.p.A. | Via Bovazecchino, Badia Polesine (RO) italy) was mixed according to manufacturer instructions and the crowns of the teeth were inserted in the mix 2mm below cemento-enamel junction. They were then cut bucco-lingually to be used to measure the thickness of preparation. Each preparation was done with a fresh set of stones (#ZR 850 FG.01, Komet USA, Rock Hill, SC Komet USA) to standardize the process. To stabilize the teeth during preparation, they were put on a specially made gypsum platform with a spherical hole in the middle. Keeping the preparation angle stable by coupling the handpiece to the surveyor arm.

Following the occlusal anatomy, group (E) were prepared in enamel while group (B) were prepared in dentin with sharp margin preparation (butt joint) without finish line and 45 degrees between buccal and palatal cusps. (Figure 1)

Construction of Veneers

Utilizing the Cerec Omnicam intraoral scanner teeth were previously scanned prior to dental preparation. After teeth preparation, each sample were rescanned using the previously saved scan (Biogeneric copy) to restore the anatomy of the tooth. The virtual die spacer was set at 50 µm, and the programme specified the thickness of the occlusal veneers (0.3 or 0.6 mm). Forty occlusal veneers were milled using vita suprinity blocks divided into two different thicknesses. Following milling, the occlusal veneers were vacuum-cooled and crystallised for 30 minutes at 850°C in the programat P300 ceramic furnace (Ivoclar Vivadent, Schaan, Liechtenstein).

Preparation for cementation

Following the manufacturer's instructions, the occlusal veneers were abraded with 50 µm aluminum oxide particles at 1.8 bar of pressure, dried with pressurized oil-free air after being washed with alcohol, then salinized for 60 seconds with a silane coupling agent.

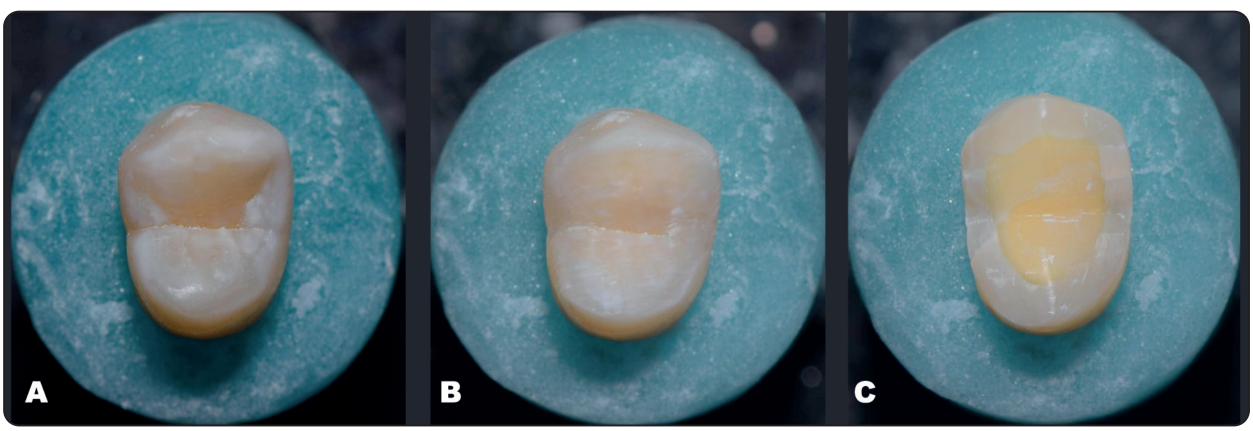

Fig (1) A Intact tooth without preparation B: Type 1 preparation (within Enamel) C: Type 2 preparation (within Dentine)

With care to avoid over-drying, the prepared teeth were rinsed with water and dried with air. Then using 37.5% phosphoric acid, enamel and dentine of occlusal surfaces were etched for 15 seconds and then they were totally rinsed and blot dried without dehydrating the dentin using 2 bar pressure for 10 seconds on a distance of 10 mm.

Using self-adhesive, dual-cure resin cement (TheraCem), the restorations were cemented. Each occlusal veneer was placed on its matching tooth and stabilized for setting while a seating pressure of statistic load of 50 N was provided for 10 minutes to simulate finger pressure[11]. The luting agent was cured using light curing device for 30 seconds in five different directions. A thin layer of anti-oxygen seal was placed to the restoration margin. All the samples were subjected to thermo cycling (SD Mechatronic Thermo cycler. Westerham. Germany) for 5000 cycles 5-55 ± 2 °C with a one-minute and a 10 seconds interval.

Using universal testing machine (INSTRON-CAT.NO:2710-115.USA) fracture test was performed with a rounded tip steel rod (6 mm diameter) and a crosshead speed of 1mm/min, utilizing a compressive mode of stress delivered occlusally with the long axis of the tooth. (Figure 2) A 0.5mm tin foil sheet was placed between the tip of the rod and the occlusal surface to achieve homogenous stress distribution. At an audible fracture and a rapid drop in the deflection of loading curve, maximum load at failure was measured using computer software in Newton.

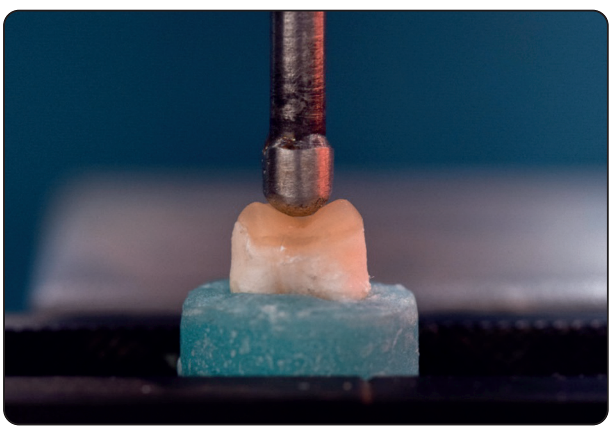

Fig. (2) Steel rod with a round tip used in fracture test

Statistical Analysis

The researcher checked, coded, and examined the gathered data using IBM-SPSS/PC/VER 24 (Statistical Package for Social Sciences) *. Characteristic statistics Calculations were made for means, standard deviations, medians, ranges, and percentages. The normality of the data was tested using the Shapiro-Wilk test. The t-test for student samples was employed to examine the variation in group means. A one-way ANOVA test along with a post-hoc analysis test was employed to examine the variation in means among different groups. P-values below 0.05 were regarded as significant.

RESULTS

After ageing, no sample displayed any chips, cracks, or fractures.

Effect of substrate luted surface:

There was statistically non-significant difference between the groups regarding the mean of the fracture resistance test results ($p = 0.297$). There was non-significant higher mean fracture load with group-D (Dentin) (1415.6 ± 300.3N) compared with group-E (Enamel) (1277.7 ± 272.7N) Table (1) Figure (3)

Effect of Restoration thickness:

There was statistically significant difference between the sub-groups regarding the mean of the fracture resistance test results ($p = 0.005$). There was significant ($p = 0.005$) higher mean fracture load with sub-groups-I (0.3 mm) (1515.1 ± 262.8N) compared with sub-groups-II (0.6 mm) (1178.3 ± 207.4N). Table (2) Figure (4)

Statistical interaction between groups:

There was significant ($p = 0.029$) difference in the mean fracture load between groups.

In other words, sub-group-E2 (Enamel with 0.6 mm thickness) had lower mean fracture load (1119.1 ± 213.9N) compared with both sub-group-E1 (Enamel with 0.3 mm thickness) (1436.4 ± 242.1N, p=0.049) and sub-group-D1 (Dentin with 0.3 mm thickness) (1593.6 ± 285.3N, p=0.006). Also, sub-group-D1 (Dentin with 0.3 mm thickness) had higher load than sub-group-D2 (Dentin with 0.6 mm thickness) (1237.6 ± 205.5N, p=0.031). All other differences were statistically insignificant (p>0.05). Table (3) Figure (5)

Table (1): Comparison of Mean Fracture Resistance between groups

(Mean ± SD)	Group-I (Enamel) (n = 20)	Group-II (Dentin) (n = 20)	Mean Difference	P-value*
Fracture load				
Mean ± SD	1277.7 ± 272.7	1415.6 ± 300.6	**137.9**	= 0.297
Median (Range)	1305 (852-1750)	1338 (982-1973)		

Independent Sample t-test was used to compare mean before vs after treatment

Table (2): Comparison of Mean Fracture Resistance between subgroups

(Mean ± SD)	Group-I (0.3 mm) (n = 20)	Group-II (0.6 mm) (n = 20)	Mean Difference	P-value*
Fracture Load				
Mean ± SD	1515.1 ± 262.8	1178.3 ± 207.4	**336.7**	**= 0.005**
Median (Range)	1485 (1092-1973)	1183 (852-1527)		

Independent Sample t-test was used to compare mean before vs after treatment

Table (3): Comparison of Mean Fracture Resistance between groups in each group

(Mean ± SD) (n=5)	Mean ± SD	Median (Range)	P-value*
G-I (Enamel (0.3 mm))	1436.4 ± 242.1	1421 (1092-1750)	
G-II (Enamel (0.6 mm))	1119.1 ± 213.9	1125 (852-1398)	**= 0.029**
G-III (Dentin (0.3 mm))	1593.6 ± 285.3	1623 (1273-1973)	
G-IV (Dentin (0.6 mm))	1237.6 ± 205.5	1252 (982-1523)	
P-value**	**I vs II = 0.049**	**II vs III = 0.006**	I vs IV = 0.207
	I vs III = 0.313	II vs IV = 0.444	**III vs IV = 0.031**

One-way ANOVA test was used to compare mean before vs after treatment

*****Post-hoc analysis with Bonferroni Correction was used for Pairwise Comparisons***

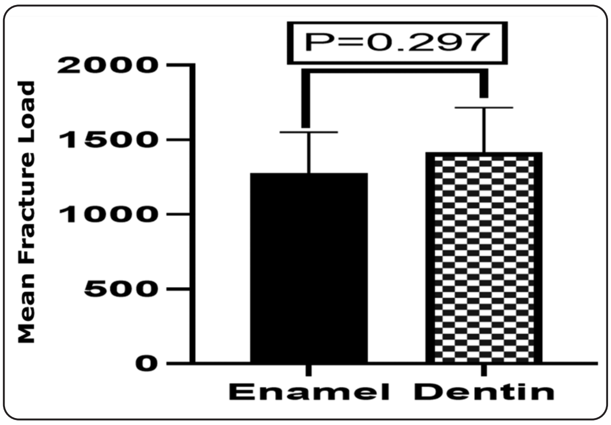

Fig. (3): Mean Fracture Load between groups

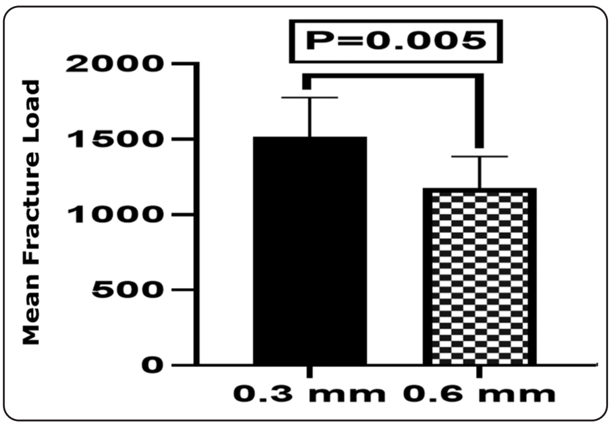

Fig. (4): Mean Fracture Load between sub-groups

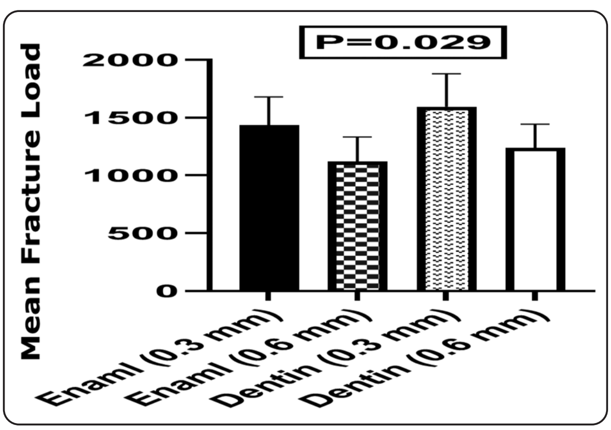

Fig. (5): Mean Fracture Load between Subgroups of each group

DISCUSSION

The term "posterior occlusal veneer" has gained widespread usage in the dental community in an effort to move toward the idea of minimally invasive dentistry in recent years, particularly in light of discernible advancements in adhesive systems and restorative material techniques[2].

The longevity of these innovative restorations depends on a number of factors, including the type and thickness of the restoration, the mechanical properties of the restorative materials, the patient's occlusal stresses, the location of the tooth being restored, the bonding substrate, and the bonding process[12].

Fast advancements in material science have also improved contemporary manufacturing techniques. Three problems were addressed by the development of computer-aided design (CAD) and computer-aided manufacturing (CAM): first, ensuring that the restoration had sufficient strength; second, ensuring that restorations looked natural; and third, simplifying, speeding up, and improving the accuracy of tooth restoration[13].

Occlusal veneers and other recently developed conservative restorations are based on the concept of micro-retention as opposed to macro-retention. Better preservation of the tooth structure is possible as long as the appropriate adhesive protocols are adhered to. Conservative dentistry can also benefit from the principles of posterior occlusal veneers, which are thin onlays or overlays with non-retentive designs. These restorations may face competition from gold overlays or onlays. Extra coronal reconstructions known as occlusal veneers require little preparation when taking into account anatomical considerations and interocclusal clearance[14].

The concept of micro-retention, as opposed to macro-retention, underpins occlusal veneers, a relatively new conservative restoration that allows for greater tooth structure preservation when the proper adhesive techniques are used[15].

The objective of this study was to compare the fracture resistance of four different designs of zirconia reinforce lithium silicate materials used in an ultrathin occlusal veneer. Authors found that the occlusal veneers with different designs already matched fracture load. While the highest fracture strength under vertical loading was found with the occlusal veneers with 0.3mm thickness bonded to dentine. In other words, in this present study neither type of preparation designs ensured superior fracture properties but occlusal veneers with 0.3mm thickness bonded to dentine has slightly better fracture resistance.

Veneers in this study were cemented to natural teeth not to composite blocks. Human natural teeth were selected because they were more elastic, bonded well, and had strength that was more appropriate for the conditions in the clinic.[16]. Premolars with similar crown and root sizes were utilized, as suggested by earlier research, maxillary teeth were selected to closely mimic and approach the clinical scenario in terms of tooth architecture and morphology[17].

It is difficult to restore human natural teeth crowns with homogeneous uniform thickness occlusal veneers due to their uneven occlusal anatomy. Because it provides standardized fabrication techniques and permits controlled restoration thickness and geometry during the fabrication process, CAD/CAM technology was chosen for this study[10].

Zirconia-reinforced lithium silicate (ZLS) was selected for this investigation. ZLS has superior mechanical behavior as it contains tetragonal zirconia fillers, this fillers decrease crack propagation[5].

The ZLS has an elastic modulus of 105 GPa and a flexural strength of 510 MPa [18] [19]. The strength of the tooth or restoration set is influenced by the elastic modulus of the material and substrate as well as the material's flexural strength.[20].

The microstructure and fatigue of the ceramic material, the manufacturing process, the final preparation design, and the luting procedure are some of the aspects that affect the fracture resistance of all-ceramic repair systems.[21].

In the current experiment, two preparation strategies were chosen: one less invasive approach that involved preparation of only the occlusal surface.

To reduce variations during bonding operations, strict adherence to the bonding protocols for each occlusal veneer design employed was established in compliance with the manufacturer's instructions. Various authors have proposed that 50 µm aluminum oxide particles be sandblasted onto the interior surface of lithium disilicate design veneers in order to increase the material's surface roughness and enhance micromechanical retention for bonding[22].

The application of silane to the ceramic surface can affect how well the ceramic restoration and resin cement bond[23]. This is because, in addition to creating a siloxane bond between the silica in the ceramic and the organic matrix of the resin cement, silane facilitates contact with the ceramic due to bi-functional molecules through additional chemical bonding[24]. Moreover, it serves as an inbuilt buffering layer that can absorb stresses during loading application, increasing the values of fracture resistance[25].

Several tests showed that the etch and rinse cementation method had the highest shear bond strength (SBS) to enamel because of its superior etching capabilities. Enamel etching step improves bonding to tooth structure and allows excellent marginal integrity[26]. The etch and rinse method is advised for bonding to enamel because the micromechanical contact produces a durable connection[27].

Seldom do authors provide a comprehensive justification for the temperature and time conditions they chose in their experimental investigations. The inability to compare study results is due to the different temperatures, dwell times, number of cycles, and bath intervals. As a result, thermal cycling produces inconsistent results. One year's worth of clinical function is equivalent to about 10,000 heat cycles. This estimate is predicated on the theory that such cycles may occur 20 to 50 times per day[(28)]. However the accepted number of cycles is 5000 cycle as suggested by many authors[(29)]. The most effective aging process is thermal cycling (5°C/55°C, 1 min)[(30)]. In the current study, thermocycling for 5000 thermal cycles (5ºC/55ºC, 1 min dwell time) is the aging strategy.

Regarding fracture resistance, age and facial morphology can affect the physiologic maximal occlusal forces, which can vary by up to 500 Newton[(31)]. According to the findings of multiple studies, the average loading force varied between 50 and 250 N, whereas parafunctional behaviors like bruxism and clenching result in loads between 500 and 800 N. For men and women, the mean maximum masticatory forces experienced in the molar region are 847 N and 597 N, respectively[(32)].

The study results showing that, hypothesis was partially rejected as statistically significant higher fracture resistance values were recorded for subgroup III (dentine 0.3mm) (1593.6 ± 285.3 N, p=0.006) compared to sub group II sub-group-II (Enamel with 0.6 mm thickness) had lower mean fracture load (1119.1±213.9 N). However, for preparation design (bonded surface), the mean values have no significance in all study groups. In other words, The occlusal veneers with a thickness of 0.3 mm had a greater fracture load than those with a thickness of 0.6 mm, indicating that an ultrathin thickness of 0.3 mm may still achieve high strength even under conditions of continual fracture stress. Consequently, when comparing the thicknesses of 0.6 and 0.3 mm, the greater thickness did not influence the fracture load values.

This was in agreement with ***Valenzuela, et al (2021)***[(9)] who stated that in fracture resistance only the thickness factor was significant regardless bonded surface.

This also was in correlation with ***Emam, et al. (2020)***[(1)] who examined how different preparation schemes and materials affect the occlusal veneers made using CAD/CAM in terms of their fracture resistance and marginal fit. They found that when fixing thickness of restoration, all groups showed comparable and insignificant fracture resistance.

This is in agreement with findings reported in the literature by ***Elsayed.(2021)***[(33)] They examined the fracture resistance of hybrid ceramics attached to various bonding protocols and thin and ultra-thin occlusal veneers made of glass ceramics. Between bonding techniques, there was a statistically significant difference whereby immediate dentin sealing (IDS) exhibited the highest statistically significant mean fracture resistance, followed by enamel and finally delayed dentin sealing (DDS).

This was in agreement with ***Sasse et al. (2015)*** [(34)] who showed that ultrathin (0.3–0.6 mm) restorations luted to dentin had a greater fracture stress than restorations luted to enamel alone. Regarding the thickness of the restoration, the findings showed higher fracture resistance for thicker veneers. This difference may be related to the different luting protocols, as Sasse et al. followed the self-etch primer protocol.

Krummel et al (2019)[(35)] further achieved increased fracture resistance for the restorations luted to dentin by selectively etching the surrounding enamel with an enamel-etching procedure.

Piemjai et al (2007)[(36)] who has revealed that restorations luted to enamel had a higher fracture load than restorations luted to dentin which does not coincide with my results. The discrepancies in the results could be attributed to methodological variations across studies, including the way the occlusal veneer was prepared, how thick the restorations were, and what kind of mechanical loading was used.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

1- Minimal thickness of 0.3 mm found to be tolerable for occlusal masticatory forces with satisfactory acceptance.

2- Every occlusal veneer design put to the test was able to tolerate both parafunctional and normal masticatory stresses.

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