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# Comparison of Fracture Load and Surface Wear of Microhybrid Composite and Ceramic Occlusal Veneers

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**Keywords**
Fiber-reinforced microhybrid composites; fracture load; lithium disilicate ceramic; microhybrid composites; occlusal veneer; surface roughness; surface wear.

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## Abstract

**Purpose:** To compare in vitro fracture load, surface wear, and roughness after thermal cycling and cyclic mechanical fatigue loading among cemented microhybrid resin-based composite and ceramic occlusal veneers fabricated at two thicknesses (1.5 and 2.5 mm).
**Materials and methods:** Sixty-four extracted premolars without root canal treatment were prepared and restored with occlusal veneers of two thicknesses (1.5 and 2.5 mm), using four different materials: microhybrid composite (MC), fiber-reinforced microhybrid composite (FMC), heat-pressed lithium disilicate ceramic (HPC), and computer-aided design/computer-aided manufactured lithium disilicate ceramic (CCC). The specimens underwent thermal cycling and cyclic mechanical fatigue loading, and were then subjected to fracture testing, with loads at failure recorded as fracture load. Wear and surface roughness were recorded before and after fatigue loading. Results were analyzed using one-way ANOVA, two-way ANOVA ($\alpha = 0.05$).
**Results:** All specimens survived thermal cycling and cyclic mechanical fatigue loading. At 1.5-mm thickness, the mean fracture load of FMC was highest (3926.48 ± 556.54 N), while that of CCC was highest (3066.45 ± 559.94 N) at 2.5 mm. Regardless of thickness, the fracture load of CCC was higher than that of HPC ($p = 0.004$ and $p = 0.023$). The wear of MC and FMC was significantly higher than those of HPC and CCC ($p \leq 0.001$), but was similar in terms of the wear rate of tooth enamel. HPC exhibited the lowest surface roughness after fatigue loading ($p \leq 0.001$).
**Conclusion:** All tested occlusal veneers exhibited a fracture load considerably exceeding the maximum occlusal force in the posterior dentition. When the attainable space for restoration varies, different occlusal veneer materials should be considered. The surface wear and roughness also need to be considered when selecting materials.

Tooth wear is primarily caused by erosion, bruxism, or a combination thereof. Severe wear of teeth may result in the loss of vertical dimension of occlusion and symptoms of dentin sensitivity. With recent advances in adhesive dentistry, adhesive restorations, such as occlusal veneers, are used to restore moderate to severe tooth wear with minimal preparation.[1] They reduce the need for root canal treatment and unnecessary destruction of remaining tooth substance. They are also associated with less gingival inflammation and secondary caries. The vertical dimension of occlusion usually needs to be increased when restoring moderate to severe tooth wear. The common range of increased vertical distance is 2-5 mm and the common thickness of occlusal veneer is 1.5-2.5 mm.[2,3]

For patients with moderate to severe tooth wear, restorations may be exposed to stronger forces than in individuals with normal tooth wear; these restorations are likely to be subjected to heavy loading, resulting in an increased risk for fracture.[4] Therefore, restorative materials should be able to withstand these occlusal forces when bonded to the tooth/teeth. Restoration fractures are the most important cause of failure of restorations in cases of moderate to severe tooth wear.[5]

To date, many different materials have been used to fabricate occlusal veneers, including microhybrid resin-based composites (MC), fiber-reinforced microhybrid resin-based composites (FMC), heat-pressed lithium disilicate ceramic (HPC), and computer-aided design (CAD)/computer-aided manufactured (CAM) lithium disilicate ceramic (CCC). Lithium disilicate ceramic exhibits good fracture load, wear resistance, and a smooth surface, and is usually used to fabricate adhesive restorations. However, ceramic is a brittle material and requires sufficient thickness to ensure sufficient resistance to fracture load. Resin-based composite is less brittle and can achieve higher fracture load when it is thinner.[6-8]

Fiber-reinforced composites (FRC) have the significant ability to withstand tensile stress and to stop–or, at least mitigate–crack propagation.[9] The use of FRC may increase the fracture strength and have a beneficial effect on the failure mode of composite resin restorations, as well as their ability to be repaired in cases of fracture.[10]

In previous studies, the fracture resistance of occlusal veneers of different thickness and materials has been compared, with no consistent conclusion.[11,12] Further research is required regarding the selection of the most suitable material for occlusal veneers of different thickness.

The wear properties of restorations are an important factor in maintaining stable occlusal relations. The difference between the wear of restorative materials and natural teeth may lead to problems with esthetics, periodontal and occlusal function.[13,14] In addition, rough restoration surfaces are associated with aesthetic problems, caries, periodontal problems, and increased wear of the opposing teeth. Furthermore, smooth surfaces reduce plaque accumulation and bacterial adhesion.

Therefore, the present in vitro study was designed to compare the fracture load, surface wear, and roughness of occlusal veneers among microhybrid composites, with and without fiber-reinforcement, and lithium disilicate ceramics fabricated by two methods, at two thickness (1.5 and 2.5 mm), after thermal cycling and cyclic mechanical fatigue loading. The first null hypothesis was that the fracture load of occlusal veneer is independent from its thickness and type of material. The second null hypothesis was that the surface wear and roughness of occlusal veneer are independent of its type of material.

## Materials and methods

For this study, 64 caries-free maxillary human premolars of nearly the same size, with no obvious crack(s), and recently extracted for orthodontic reasons, were collected. This study was conducted in accordance with all the provisions of the local human subjects' oversight committee guidelines and policies of the Bioethics Committee of Peking University Hospital of Stomatology. The approval code for this study is PKUSSIRB-201734028. The teeth were stored in a solution of 0.02% sodium azide for a maximum of 1 month from the time of extraction. The roots were covered with polytetrafluoroethylene (0.2 mm thick) to simulate the periodontal ligament before being mounted. The teeth were then mounted using acrylic resin, embedding the root up to 3 mm below the cementoenamel junction (CEJ) to simulate the human alveolar bone.

The embedded teeth were prepared using high-speed diamond rotary instruments (TR-13, DIA-BURS, MANI Inc., Utsunomiya, Japan) to simulate moderate to severe tooth wear. An average of approximately 1.5 mm of occlusal surface was removed. The peripheral axial enamel was intact and the cusp inclinations were nearly 20°.

The prepared teeth were divided into two groups randomly. Group 1 was restored with occlusal veneer at a thickness of 1.5 mm and Group 2 was restored with occlusal veneer at a thickness of 2.5mm. Group 1 and Group 2 were randomly divided into four subgroups ($n = 8$/group) according to the materials of occlusal veneers. The four fabrication materials included the following: MC (Ceramage, Shofu Inc., Kyoto, Japan); FMC (everStick C&B, GC, Tokyo, Japan); HPC (IPS e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein); and CCC (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein). The occlusal veneers of all groups were fabricated with a uniform thickness, both at the cusp and the fissure.

The occlusal veneers of the MC group were fabricated using the build-up technique. The occlusal veneers were light cured and heated for 5 min using a Solidilite (Shofu Inc., Kyoto, Japan) with a light wave spectrum of 400–550 nm after being built up to the final form and subsequently glazed (Luxatemp-Glaze & Bond, DMG, Hamburg, Germany).

The process of fabrication of FMC occlusal veneers was as follows (Fig 1). First, a thin layer of composite resin was placed on the occlusal surface of the tooth preparation, then a branch of FRC fiber was flattened and placed to form an FRC base. The direction of the FRC fiber was buccolingual and the thickness of the fiber layer was 0.2 mm. After light curing and heating (Solidilite, Shofu Inc., Kyoto, Japan) for 5 min, the excess FRC was removed using a carbide rotary instrument. The FRC base was then treated with modeling liquid (Ceramage, Shofu Inc., Kyoto, Japan) and the composite resin was built up incrementally to the final form. After polymerization, the occlusal veneers were glazed (Luxatemp-Glaze & Bond, DMG, Hamburg, Germany) and finally polymerized. Each specimen of FMC and MC group was polymerized three times and 5 min every time.

The occlusal veneers of the HPC group were fabricated using the lost-wax technique and then glazed (IPS e.max Ceram, Ivoclar Vivadent, Schaan, Liechtenstein). Occlusal veneers in CCC group were fabricated using a chair-side CAD/CAM system. The prepared teeth were scanned using a three-dimensional (3D) scanner (CEREC AC, Sirona, Benshein, Germany). Occlusal veneers were designed in CAD-software (CEREC Premium), fabricated using a milling machine (CEREC MC, Sirona, Benshein, Germany), and then crystallized (Programat P310, Ivoclar Vivadent, Schaan, Liechtenstein). Final glazing was performed (IPS e.max Ceram, Ivoclar Vivadent, Schaan, Liechtenstein) after crystallization.

For the HPC and CCC groups, the bonding surfaces of the occlusal veneers were air-abraded using aluminum oxide powder (50 $\mu$m), then cleaned with 75% alcohol and dried with oil-free pressurized air. A 4.5% hydrofluoric acid etching gel was used to etch the bonding surface for 30 s, then the bonding surfaces were pretreated with adhesive primer for porcelain bonding (Porcelain Liner M, Sun Medical, Moriyama, Japan). For the MC and FMC groups, the bonding surfaces were

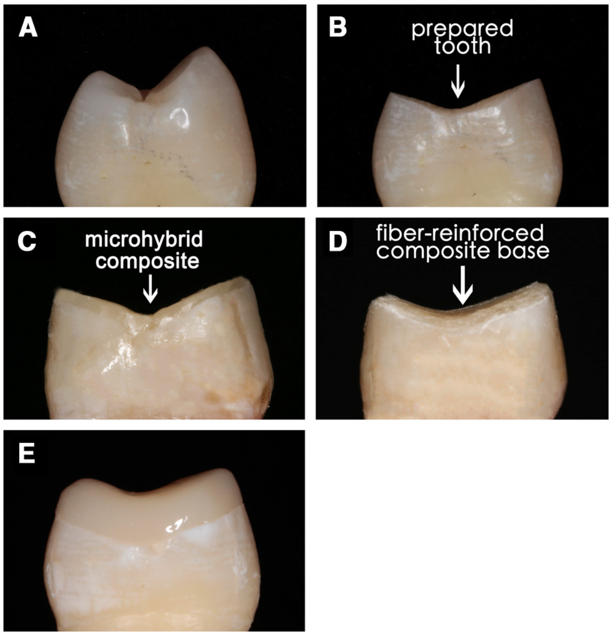


**Figure 1** Fabrication of a fiber-reinforced microhybrid composite occlusal veneer. A, the extracted tooth before preparation. B, the prepared tooth. C, placement of a thin layer of microhybrid composite. D, the fiber-reinforced composite base. E, the complete occlusal veneer.

cleaned using 75% alcohol and dried with oil-free pressurized air.

All occlusal veneers were cemented to tooth preparations using resin cement (Superbond C&B, Sun Medical, Moriyama, Japan) according to the manufacturer's recommendations, while a seating load of 10 N was applied for 5 min; the excess cement was then removed. After cementation, all specimens were returned to distilled water storage for at least 3 days before thermal cycling and cyclic mechanical loading.

To mimic intraoral conditions and 5 years of clinical service, all specimens were fatigued in a chewing simulator previously developed by the authors. Stainless steel spheres with a 5.5-mm diameter were used as antagonists. Antagonists moved vertically while loading stages moved horizontally in the fore-and-aft direction. Antagonists dropped down with weights mounted on vertical bars and first contacted the triangular ridge of the buccal cusp, then moved to the triangular ridge of the lingual cusp, and finally, left the occlusal surface. The loading acted both vertically and horizontally at the same time to mimic the chewing circle of posterior teeth. Specimens were cyclically loaded 1,200,000 times with a force of 50 N at a frequency of 1.3 Hz, and thermal cycled in water between 5°C and 55°C, with a 60-s dwell time at each temperature and a 12-s interval between temperature shifts (approximately 6400 cycles in total).

The contact areas of all specimens were observed at a magnification of 400×. Surface roughness was measured using a 3D laser scanning confocal microscope (VK-X200, Keyence, Osaka, Japan) before and after thermal cycling and cyclic mechanical loading, and the mean roughness (i.e., Ra [$\mu$m]) was recorded.

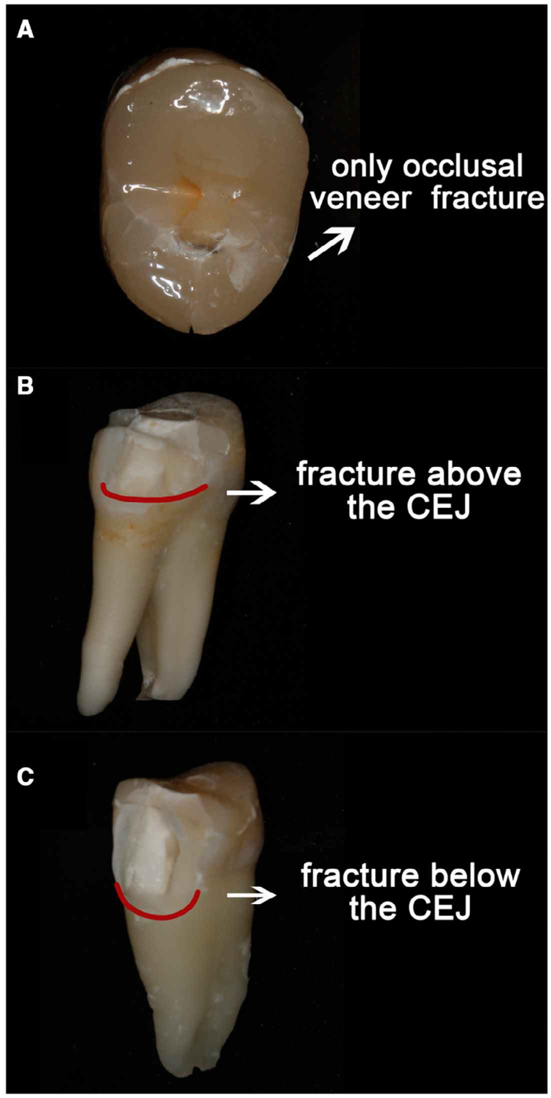


**Figure 2** The fracture modes. A, fracture mode 1. B, fracture mode 2. C, fracture mode 3.

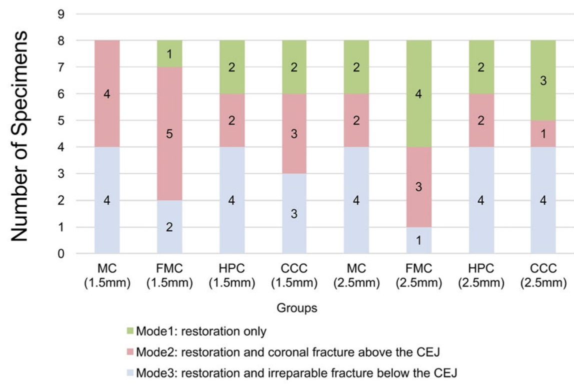


**Figure 3** The fracture modes. MC, microhybrid composite; FMC, fiber-reinforced microhybrid composite; HPC, heat-pressed lithium disilicate ceramic; CCC, computer-aided design/computer-aided manufactured (CAD/CAM) lithium disilicate ceramic. CEJ, cemento-enamel junction.

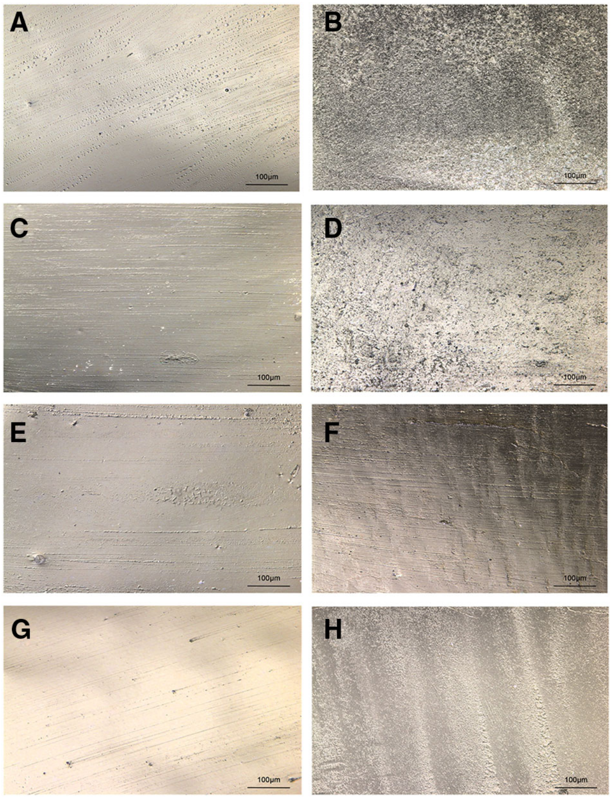


**Figure 4** Surface image of the occlusal contact area before and after thermal cycling and cyclic mechanical loading (×400). A, microhybrid composite, before the test. B, microhybrid composite, after the test. C, fiber-reinforced microhybrid composite, before the test. D, fiber-reinforced microhybrid composite, after the test. E, heat-pressed lithium disilicate ceramic, before the test. F, heat-pressed lithium disilicate ceramic, after the test. G, computer-aided design/computer-aided manufacturing (CAD/CAM) lithium disilicate ceramic, before the test. H, CAD/CAM lithium disilicate ceramic, after the test.

To assess wear, impressions of specimens were made using addition silicone impression material (Variotime, Heraeus, Hanau, Germany) and super-hard gypsum replicas (Pemaco, Pemaco, Saint Louis, MI) were prepared before and after fatigue loading. The gypsum replicas were scanned using a 3D laser scanner (Smart Optics 880 Dental, Smart Optics, Bochum, Germany). The 3D digital images of the specimens before and after fatigue loading were matched (best-fit alignment), and differences were analyzed (3D Compare) using Geomagic 2014 software. The wear of the occlusal veneers (average distance of difference before and after fatigue loading) was recorded.

After thermal cycling and cyclic mechanical loading, all groups of veneers were subjected to a fracture test to measure fracture load and mode. The test was performed at a temperature of 25°C using a universal testing machine (Instron 5969, Instron, Boston, IL). A stainless steel sphere with a 5.5-mm diameter was used in parallel with the long axis of the tooth in the occlusal contact area. The crosshead speed was 1.0 mm/min. The load was applied until fracture occurred, and the load (N) at failure was recorded when at least two of the three following conditions were met: a sharp decline in the load curve; visible signs of fracture were observed; or audible emissions, caused by the generation of elastic waves by crack formation and/or progression, were heard.[15]

The fracture mode was classified and noted as being in one of three categories (Fig 2): occlusal veneer only, occlusal veneer and coronal fracture above the CEJ, or occlusal veneer and irreparable fracture below the CEJ. Mode 1 and mode 2 could be retreated; mode 3, however, was considered to be unrecoverable.

Two-way ANOVA was performed to determine the effects of the type of material and its thickness on the fracture load and their interaction. One-way ANOVA was performed to compare the surface roughness and wear. The level of significance was set at $\alpha = 0.05$. Statistical analyses were performed using SPSS version 20 (IBM Corporation).

## Results

All specimens survived thermal cycling and cyclic mechanical loading without fracture and no fibers were exposed in the FMC group. The means of fracture load and surface wear after fatigue loading as well as surface roughness before and after fatigue loading are shown in Table 1.

Two-way ANOVA revealed significant differences in fracture load among the four materials and two thicknesses ($p \leq 0.001$ and $p \leq 0.001$, respectively). There was a significant interaction between the type of material and thickness ($p \leq 0.001$). The Pairwise comparisons (LSD test) of the fracture loads are shown in Table 2. For the 1.5-mm occlusal veneers, the fracture load of the FMC group was significantly higher than those of the other three groups. HPC had the lowest fracture load, which was significantly lower than those of the other three groups. At a thickness of 2.5 mm, the CCC group demonstrated the highest fracture load among the groups, while the MC, FMC, and HPC occlusal veneers exhibited similar fracture loads ($p > 0.05$). The Pairwise comparisons revealed significant differences in the fracture loads of the MC and FMC groups between the 1.5 and 2.5 mm thickness ($p \leq 0.001$ and $p \leq 0.001$, respectively). There were no significant differences in the fracture loads of the HPC and CCC groups between the two thickness ($p = 0.325$ and $p = 0.743$, respectively).

The fracture modes of the different groups are shown in Figure 3. At a thickness of 1.5 mm, the FMC group exhibited 25% of fractures below the CEJ, while the other three groups exhibited 37.5% to 50%. For the 2.5-mm occlusal veneers, the FMC group exhibited only 12.5% of fractures below the CEJ, in contrast to the other groups that exhibited 50% of fractures below the CEJ.

Surface wear and roughness are not correlated with material thickness; therefore, only differences among the different materials were compared, ignoring thickness. Since no fibers were exposed in the FMC group after fatigue loading, FMC group was indeed the same as MC group when surface wear and roughness were compared. The one-way ANOVA results of surface wear and roughness are shown in Tables 3 and 4. After fatigue loading, the wear of the MC and FMC groups was significantly higher than that of the two ceramic groups ($p \leq 0.001$). The surface roughness of the two types of

**Table 1** Fracture load, surface wear and roughness of occlusal veneers

| Materials | Thickness (mm) | Fracture load (N) | Surface wear (mm) | Surface roughness (μm) | |
|---|---|---|---|---|---|
| | | | | Before fatigue loading | After fatigue loading |
| | | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) |
| MC | 1.5 | 3237.29 (514.29) | −0.13 (0.03) | 1.23 (0.21) | 1.81 (0.27) |
| | 2.5 | 2284.95 (436.58) | | | |
| FMC | 1.5 | 3926.48 (556.54), | −0.13 (0.03) | 1.29 (0.17) | 1.89 (0.25) |
| | 2.5 | 2488.92 (630.51) | | | |
| HPC | 1.5 | 2249.57 (375.80) | −0.05 (0.01) | 0.73 (0.12) | 1.45 (0.21) |
| | 2.5 | 2493.39 (493.24) | | | |
| CCC | 1.5 | 2985.64 (259.05) | −0.05 (0.01) | 0.73 (0.13) | 1.75 (0.18) |
| | 2.5 | 3066.45 (559.94) | | | |

MC, microhybrid composite; FMC, fiber-reinforced microhybrid composite; HPC, heat-pressed lithium disilicate ceramic; CCC, computer-aided design/computer-aided manufactured (CAD/CAM) lithium disilicate ceramic.

**Table 2** Pairwise comparisons of the fracture loads. (LSD test)

| Groups | Versus | *p*-Value | Groups | Versus | *p*-Value |
|---|---|---|---|---|---|
| MC (1.5mm) | FMC (1.5mm) | 0.007 | MC (2.5 mm) | FMC (2.5 mm) | 0.409 |
| | HPC (1.5mm) | ≤0.001 | | HPC (2.5 mm) | 0.399 |
| | CCC (1.5mm) | 0.310 | | CCC (2.5 mm) | 0.002 |
| FMC (1.5mm) | HPC (1.5mm) | ≤0.001 | FMC (2.5 mm) | HPC (2.5 mm) | 0.986 |
| | CCC (1.5mm) | ≤0.001 | | CCC (2.5 mm) | 0.022 |
| HPC (1.5mm) | CCC (1.5mm) | 0.004 | HPC (2.5 mm) | CCC (2.5 mm) | 0.023 |

MC, microhybrid composite; FMC, fiber-reinforced microhybrid composite; HPC, heat-pressed lithium disilicate ceramic; CCC, computer-aided design/computer-aided manufactured (CAD/CAM) lithium disilicate ceramic.

**Table 3** One-way ANOVA results of the surface wear. (Dunnett T3 test)

| Groups | Versus | *p*-Value |
|---|---|---|
| MC | FMC | 1.000 |
| | HPC | ≤0.001 |
| | CCC | ≤0.001 |
| FMC | HPC | ≤0.001 |
| | CCC | ≤0.001 |
| HPC | CCC | 0.949 |

MC, microhybrid composite; FMC, fiber-reinforced microhybrid composite; HPC, heat-pressed lithium disilicate ceramic; CCC, computer-aided design/computer-aided manufactured (CAD/CAM) lithium disilicate ceramic.

**Table 4** One-way ANOVA results of the surface roughness. (LSD test)

| Surface roughness before fatigue loading | | | Surface roughness after fatigue loading | | |
|---|---|---|---|---|---|
| Groups | Versus | *P*-value | Groups | Versus | *p*-Value |
| MC | FMC | 0.337 | MC | FMC | 0.312 |
| | HPC | ≤0.001 | | HPC | ≤0.001 |
| | CCC | ≤0.001 | | CCC | 0.529 |
| FMC | HPC | ≤0.001 | FMC | HPC | ≤0.001 |
| | CCC | ≤0.001 | | CCC | 0.104 |
| HPC | CCC | 0.950 | HPC | CCC | ≤0.001 |

MC, microhybrid composite; FMC, fiber-reinforced microhybrid composite; HPC, heat-pressed lithium disilicate ceramic; CCC, computer-aided design/computer-aided manufactured (CAD/CAM) lithium disilicate ceramic.

composite occlusal veneers were significantly higher than those of the two ceramics ($p \leq 0.001$) before thermal cycling and cyclic mechanical loading. After loading, the surface roughness of all four groups increased, and the roughness of the HPC group was significantly lower than those of the other three groups ($p \leq 0.001$). Representative surface images before and after fatigue loading are shown in Figure 4.

## Discussion

It was hypothesized that the fracture load of occlusal veneer is independent from its thickness and type of material. The second hypothesis tested was that the surface wear and roughness of occlusal veneer are independent of its type of material. Based on the outcome of the statistical analysis, both hypotheses were rejected.

The fracture load of occlusal veneer depends both on the physical properties of the material and its thickness. When the thickness of occlusal veneers was 1.5 mm, the fracture load of FMC was significantly higher than that of MC, HPC, and CCC. When the thickness increased to 2.5 mm, the CCC group demonstrated the highest fracture load. The maximum bite force in the posterior area of adults ranges from 300 to 880N, therefore all four materials are acceptable in clinic from the point of fracture load.[16] FRC is able to withstand tensile stress and prevent crack propagation so that increased the fracture strength of composite resin material. The FRC used in this study (everStick C&B) is made from silanated unidirectional glass fibers and impregnated with poly(methylmethacrylate) (PMMA) and bis-GMA (bisphenol-glycidyl methacrylate). Jelena et al found the fracture strength of everStick C&B (370.5 MPa) was significantly higher than that of composite resin (87.8 MPa).[17] The composite resin can penetrate into the everStick, which produce chemical and mechanical bonding between composite resin and the fiber, to form a stronger structure. For the 1.5-mm occlusal veneers, the fracture load of the FMC group was significantly higher than MC group, however, in the 2.5-mm occlusal veneers, there was no significant difference. When the thickness of FMC occlusal veneers increased to 2.5 mm, the distance between the fibers and the occlusal surface–where cracks initiated–increased and, as such, the strengthening effect of the fibers was weakened.[10] If another layer of fibers is added to the upper portion of 2.5-mm-thick occlusal veneers to decrease the distance between the fiber layer and the occlusal surface, the fracture load would probably be higher. When it comes to fracture mode, the FMC group exhibited less fractures below the CEJ than other groups at both thicknesses. This finding was consistent with the conclusion of Heumen, that FRC have a beneficial effect on the failure mode of composite resin restorations and decrease the unrecoverable fracture.[18]

Regardless of the thickness (i.e., 1.5 or 2.5 mm), the fracture load of the CCC group was higher than that of the HPC group. Although CCC and HPC have the same material composition, different manufacturing methods will result in different mechanical properties.[19] The crystal length and width of IPS e.max Press are approximately 4 and 0.6 $\mu$m while IPS e.max CAD are 1 and 0.4 $\mu$m. The length and width of crystal affect the fracture load of ceramics.[20] The proportion of nucleating agent also affects the transparency and strength of heat-pressed ceramics. Fabian found that the fracture strength of CAD/CAM ceramic was higher than heat-pressed ceramic regardless of their translucency, which is in accordance with our finding.[19] In addition, the surface roughness of HPC group was significantly lower than that of CCC group after fatigue loading, which was different from two previous studies.[21,22] In this study, roughness of occlusal veneer's contact area was measured after fatigue loading. While in most of other studies, roughness of ceramic blocks was measured directly after being manufactured. As a result, the value of roughness differs.

The specimens in this study were prepared with straight-beveled finishing line without chamfer. Clausen found the design of the finishing line (straight-beveled finishing line and chamfer finishing line) did not influence the fracture resistance and different preparation designs (completely within enamel or within dentin) showed no significant influence on fracture resistance.[23]

Due to the development of non-prep veneers in the anterior region, a question arises as to whether ultrathin occlusal veneers can be used in the posterior region to restore large erosion defects without sacrificing further tooth substances. Martin and Paolo found that a veneer thicker than 0.8-1.0 mm may represent a suitable threshold for this type of restoration.[24,25] Krummel found that a treatment with occlusal ceramic veneers with a minimum thickness of 0.3-0.6mm seems to be a promising option for clinical use and additional etching of enamel improved the fracture resistance when bonding to dentin and enamel.[26] Lithium disilicate ceramic, zirconia-reinforced lithium silicate ceramic, polymer-infiltrated ceramic and PMMA exhibited a good fracture resistance and they might present a viable long-term treatment for ultrathin occlusal veneers.[27]

After fatigue loading, the wear of the MC and FMC groups was significantly higher than that of the two ceramic groups. According to previous research, when the opposing tooth is natural, the average rate of wear of the occlusal contact areas was approximately 20 to 40 $\mu$m per year in premolars and molars.[28,29] The wear rate of the MC group in this study was approximately 25 $\mu$m per year, which is nearly the wear rate of natural enamel; the wear rate of the ceramics was approximately 10 $\mu$m, which was lower than that of natural enamel. From the perspective of wear rate, MC was more favorable. This finding was in agreement with previous studies by Hahnel and Han, which compared the wear rate of composite resins with different fillers, and found that composite resin with microhybrid filler demonstrated better wear resistance and was comparable to natural enamel.[30,31]

This study still has some limitations. Firstly, the intraoral environment is hard to completely simulate through thermal cycling and cyclic mechanical loading because of its complex and individual difference. The chewing simulator was used to accelerate the aging process, after the simple and stable thermal cycling and cyclic mechanical loading, the comparison of the fatigue performance of different specimens can provide a laboratory basis for clinical application. The vertical biting force in posterior teeth ranges from 20 to 140 N-depending on the consistency of the food items.[32] An average force of 50N was applied in this study to simulate the average biting force of posterior teeth, but the food between teeth was not simulated.[15,33] Secondly, the fatigue performance of occlusal veneers of only two thickness (1.5mm and 2.5mm) was compared. In clinical application, there are more thickness variation. Finally, the prepared teeth in this study were fresh-cut but the occlusal surface of most of severe worn teeth is sclerotic dentin, in which condition the adhesive strength may decrease.

## Conclusion

All tested occlusal veneers exhibited a fracture load considerably exceeding the maximum occlusal force in the posterior dentition. When the attainable space for restoration varies, different occlusal veneer materials should be considered. When the restorative space of occlusal veneer is thin (1.5mm), FMC is recommended. When the space increases to 2.5mm, CCC is recommended.

Because the wear rate is closer to that of enamel on posterior teeth, MC has an advantage in maintaining stable occlusal relations compared with ceramics.

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