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IN VITRO STUDY TO EVALUATE THE EFFECT OF DIFFERENT MATERIAL TYPES AND PREPARATION DESIGNS ON THE FRACTURE RESISTANCE OF OCCLUSAL VENEERS

Abdelrahman M. Abdelhameed*, Mohammed H. Abd-El Aziz** *and* Tamer A. Hamza***

ABSTRACT

Purpose The purpose of this invitro study was to evaluate the effect of different ceramic material types and preparation designs on the fracture resistance of occlusal veneers. **Statement of the problem**: Thin bonded posterior occlusal veneers constitute a conservative alternative to traditional complete coverage crowns in treatment of severely worn dentition. **Materials and Methods**: Sixty extracted human maxillary first molars were randomly distributed into two equal groups (30 teeth for each) according to the preparation design: Non-ferrule(NF) and Ferrule (F). Each of group was divided into three subgroups according to the type of ceramic materials: IPS e.max CAD (LD), Lava™ Ultimate CAD/CAM (RNC) and Vita suprinity® PC (ZLS). The occlusal veneers were cemented over their respective teeth with resin cement Total Cem automix. The fracture resistance was determined by using a computer-controlled material's testing machine with a load cell of 5 kN, and data were recorded using computer software **Results**: The mean values of Fracture resistance of the NF Group were (1730.0 ± 367.2, 1785.6 ± 604.1, 1860.5 ± 354.6) for the LD, RNC, and ZLS respectively. While the mean values of Fracture resistance of the F Group were (2082.2 ± 310.6, 1752.4 ± 654.8, 1750.5 ± 435.1) for the LD, RNC, and ZLS respectively. According to ANOVA test, there was no statistically significance difference regarding the two variables (Preparation design and material type) (P=0.570 and 0.639) respectively. Also, there was no statistically significant difference regarding the interaction between the two variables in this study (P = 0.262). **Conclusion**: Within the limitation of this study, it was concluded that, Occlusal veneers made of IPS e.max CAD, Lava Ultimate, and Vita suprinity, are of comparable strength and can be used as an alternative treatment for the severely worn dentition. Also, neither the material type nor the preparation design has effect on the fracture resistance of the occlusal veneers.

INTRODUCTION

Pathological loss of tooth substance in a mechanical and/or in a chemical way is perceived globally as increasing problem [(1)]. Progressive tooth wear can lead to multiple complications if left untreated. These complications may be as simple as teeth sensitivity, tooth discoloration or pulpal complication. Moreover, loss of mineralized tooth substance may lead to impaired occlusal function and esthetic [(2)]. Therefore, the need for restorative treatment of tooth wear is necessary to prevent the negative consequences previously described [(3)].

Treatment of tooth wear requires a careful approach, depending on the degree of damage. Incipient lesions may only call for a clinical follow-up, non-invasive dentin sealing with a filled dentin bonding agent, or conservative direct composite resin restorations. However, treatment of patients with severe generalized erosion and wear is more complex. Restoring advanced tooth wear lesions by using adhesive techniques allows minimal reduction of sound dental structure. Multiple studies in the past few years suggested the use of occlusal veneers made of resin or ceramic materials as a strategic treatment for the extensive teeth loss [(4-6)]. [(4,5,6)]

* Demonstrator, Crown and Bridge Department, Faculty of Dental Medicine - Al-Azhar University. Cairo, Egypt.
** Assistant Professor, Crown and Bridge Department, Faculty of Dental Medicine - Al-Azhar University. Cairo, Egypt.
*** Professor, Crown and Bridge Department, Faculty of Dental Medicine - Al-Azhar University. Cairo, Egypt.

The use of CAD/CAM (computer-aided design/ computer-aided manufacturing) system for the fabrication of ceramic and resin occlusal veneers has overcome most of the difficulty and technical complexity of constructing these veneers[7]. Improvements were made in the CAD/CAM scanner and milling unit aiming to obtain better optical acquisitions and to produce restorations with finer details [8].

The development of ceramics that are strong "such as lithium disilicate glass ceramic and zirconia reinforced lithium silicate" but still etchable and machinable have extended the indications for bonded ceramic restorations[9-11]. Resin Nano Ceramic (RNC) has also been recently introduced for use with CAD/CAM system. Like composite resin, RNC is flexible and fracture resistant [12]. [9, 10,11] [12]

The evolution of adhesive materials and techniques has transformed the scope of dental practice. Changing concepts of restorative dentistry from cementation and mechanical retention into bonding is today's method of direct and indirect restoration of teeth [13]. Bonding to the tooth structure was found to increase the fracture resistance of dentin-bonded all ceramic restorations.[14]

Fracture resistance of occlusal veneers is one of the most important factors that can influence the rate of survival. Besides recording fracture strength values, additional data can be obtained by examination of the fractured specimens. The fracture type and its mechanics allow better understanding and comprehension of the failure mechanism, the stress distribution, and shed light on the expected performance of the tested specimens under intra-oral loading conditions [15,16,17].

Fracture resistance may not only be affected by the material type but also by the preparation design. However, their effect the fracture resistance is controversial [18-21]. [18, 19, 20, 21]

A large variability in maximal bite force has been found. Occlusal bite force may vary according to the location of the tooth in the arch, the age of the patient, the gender, or the bite habits [22]. Occlusal bite as recorded in studies can vary from 230-698 Newton [23].

METHODOLOGY

A Sixty Freshly extracted human maxillary first molars were collected. All molars were examined under 4x magnification loops (HEINE Optotechnik GmbH & Co.KG.) for any cracks, caries or old restorations. All defected teeth were excluded and replaced.

All teeth were prepared to a flat occlusal surface with no ferrule using microsaw (Isomet 4000 microsaw, Buehler, USA) with a diamond disc 0.6 mm thickness, 2500 rpm and feeding rate 10 mm/min, then thirty teeth were prepared to a circumferential chamfer finish line 1mm thickness and 1mm height with the aid of a milling surveyor (BEGO. PARASKOP, Germany) (Fig 1). Each one of the non-ferrule (NF) and ferrule (F) groups were divided into thee subgroups (10 for each) according to the ceramic materials: IPS e.max CAD (E), Lava™ Ultimate CAD/CAM (L), and Vita suprinity® PC (ZLS).

A cast model (Columbia dentoform corp. New York) was used in this study to use their teeth as a biogeneric copy during CAD/CAM fabrication, the cast model was adjusted to accommodate the size of natural teeth by slightly widening the internal surface of the maxillary first molar sockets. A custom-made index (2.0 mm thickness) was constructed to standardize the occlusal clearance for all teeth

The restoration design was accomplished by Cerec® inLab® 3D software (version 4.2) (Sirona dental system GmbH. D-64625 Bensheiu, German). The main screen of the software has five sections; Administration, scan, Model, Design and Mill. Once the first section is completed the next one is activated.

All teeth were mounted in self-cure acrylic resin (Acrostone, Acrostone Dental Manufacture, Egypt) using a plastic ring of 19 mm in diameter. All occlusal veneers were cleaned in ultrasonic cleaning device and 70% ethyl alcohol for 10 minutes to ensure a proper clean surface for the cementation.

For IPS e.max and Vita suprinity occlusal veneers, the internal surface of the restoration was etched with hydrofluoric acid 8% (DentoBond Porcelain Etch, ITENA, France) for 20 secs and rinsed with water, then dried with oil free moisture free compressed air. For Lava Ultimate™ occlusal veneers the internal surfaces were sandblasted with 50 μm aluminum oxide particles using micro-etcher (Bio-art MicroJato, Bio-art Equipamentos Odontologicos LTDA, Brazil) for 10 secs at 2 bar, then the restorations were cleaned with 70% ethyl alcohol in the ultrasonic cleaner. After that the silane coupling agent (DentoBond Porcelain Silane, ITENA, France) was brushed on the etched/sandblasted ceramic surface and dried well after one minute.

The cementation was carried out using self-adhesive resin cement (TOTAL CEM, ITENA, France). The cement material was dispensed directly into the restoration covering all surfaces. Then the restoration was seated gently on the preparation allowing the cement to flow from all sides. After removal of excess cements, the luting material was cured using a light-curing unit (3M ESPE Dental Products, St Paul, USA) For 100 secs (20 secs per surface).

All samples were individually mounted on a computer-controlled material's testing machine (Instron universal testing machine, Model 3345, England) with a load cell of 5 kN, and data were recorded using computer software (BlueHill 3 software version 3.3). Fracture test was done by compressive mode of load applied at restoration using a metallic rod with a spherical tip 6 mm in diameter that simulated an opposing cusp attached to the upper movable compartment of testing machine and traveling at cross-head speed of 1.0 mm/min. The load required to fracture was recorded in Newton.

RESULTS

Two way (ANOVA) was assessed to showing the effect of each factor and the interaction between the groups. F-test for normally quantitative variables, to compare between more than two groups. Significance of the obtained results was judged at the 5% level. Data were fed to the computer and analysed using IBM SPSS software package version 20.0. for windows.

The mean, standard deviations (±SD), minimum (Min), and maximum (Max) values of the fracture resistance measurements in Newton (N) for the ceramic materials (IPS e.max CAD, Lava Ultimate, and Vita Suprinity) and the preparation designs (ferrule and no ferrule) are presented in (Table 1) and (Fig 2, 3)

TABLE 1: Comparison between measurements of the studied groups represented by Min, Max, Mean and SD values.

Fracture Resistance		Min. – Max. (N)	Mean ± SD. (N)
Non-Ferule	E max	951.2 – 2372.0	1730.0 ± 367.2
	Lava ultimate	727.9 – 2398.6	1785.6 ± 604.1
	Suprinity	1149.3 – 2271.5	1860.5 ± 354.6
Ferule	E max	1531.6 – 2408.9	2082.2 ± 310.6
	Lava ultimate	666.8 – 2724.8	1752.4 ± 654.8
	Suprinity	1003.4 – 2417.0	1750.5 ± 435.1

According to ANOVA test, there was no statistically significance difference regarding the two variables (Preparation design and material type) (P=0.570 and 0.639) respectively. Also, there was no statistically significant difference regarding the interaction between the two variables in this study (P = 0.262) (Table 2).

Table 2: Two-way ANOVA for analysis of the factors affecting fracture resistance (preparation design and material type).

Fracture Resistance	F	p
Design	0.326	0.570
Material	0.451	0.639
Design vs Material	1.373	0. 262

The fractured specimens were collected and the mode of fracture was visually examined and classified according to Brukes' classification. According to Brukes' classification, none of the fractured samples were within class I which include minor crack or fracture of the occlusal veneers. Many of the fracture samples showed fracture mode within class II, III, and IV, but most of the fractured occlusal veneers showed catastrophic (class V) failure which include sever breakdown of restoration or combined fracture of the tooth and the restoration.

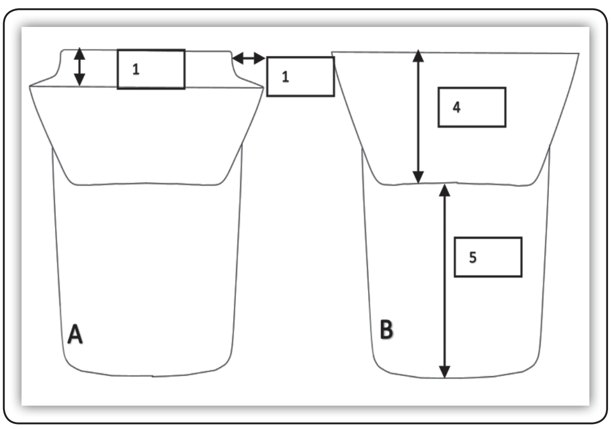

Fig. (1) Diagram showing the preparation design of the teeth from the mesial aspect; (A) Ferrule preparation design, (B) Non-ferrule preparation design. Both designs have 4 mm tooth structure above the cervical line and 5 mm tooth structure below the cervical line.

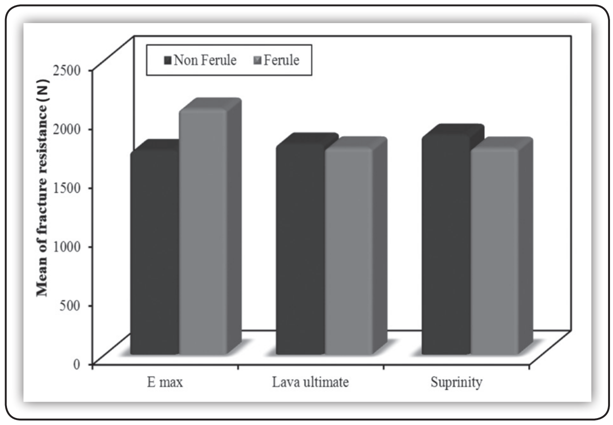

Fig. (2): Diagrammatic chart representing the mean fracture resistance (N) of the studied groups according to the material type.

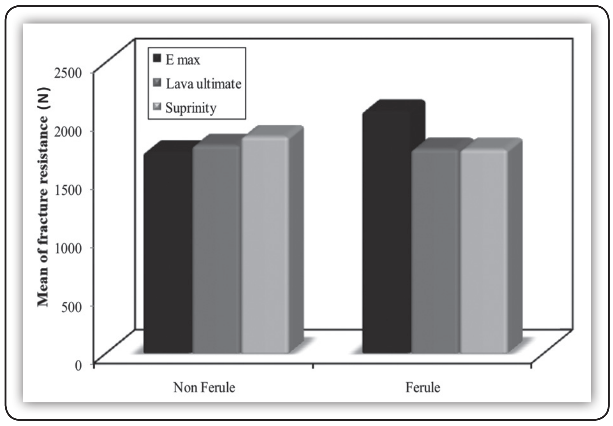

Figure (3): Diagrammatic chart representing the mean fracture resistance (N) of the studied groups according to the preparation design.

DISCUSSION

Preservation of tooth structure is a major driving force in restorative dentistry. From a biomimetic perspective, the conservation of tooth structure is paramount in maintaining the suitable equilibrium between biologic, mechanical, functional, and aesthetic parameters. It is clearly beneficial to keep the pulp vitality and prevent endodontic treatment and the need for posts and cores, because these more invasive approaches violate the biomechanical balance and compromise the performance of restored teeth over time [4,5].

Occlusal veneers are extracoronal restorations requiring a simpler and more intuitive preparation driven by interocclusal clearance and anatomical considerations [(6)].

The decision of natural teeth selection not epoxy resin or metal dies to represent better the clinical situation. Maxillary first molars were chosen because they have a high frequency of erosion-like lesions. The selection of the two designs (no ferrule and ferrule) was to evaluate a possible influence of the marginal preparation design and increasing the surface area of adhesion on the fracture resistance of the restoration.

For standardization, all teeth were cut flat using the microsaw, the finish line for the ferrule group was prepared using a milling surveyor with the same bur size, and the biogeneric copy mode was selected in the Cerec software 4.2 so that each restoration was designed and milled as an exact replica of the prepared anatomy. CAD/CAM technology was chosen due to its ability to control thickness and anatomy of restorations during the fabrication process [(7)].

It was hypothesized that the material type as well as the preparation design will influence the fracture resistance of the occlusal veneers. This hypothesis was "Rejected".

Regarding the materials, there was no significant difference in the fracture resistance between them.

Each material has its own method of strengthening mechanisms which eventually led to having comparable fracture resistance. The higher crystalline content (approximately 70% by volume) and densely packed crystalline structure of lithium disilicate (LD) in addition to an elongate grain structure is well suited to providing a respectable toughness, by inhibiting crack propagation and increase the mechanical strength [(9,10)]. On the other hand, the newly developed Zirconia reinforced lithium silicate (ZLS) contain zirconia particles ($ZrO2 \sim 10\%$) incorporated in its microstructure, this provide reinforcement for the ceramic structure by crack interruption According to the manufacturers, these materials offer mechanical properties ranging from 370 to 420 MPa. Thus, they are comparable with the clinically well-proven LD glass ceramics [(10)]. Lava Ultimate blocks contain a high proportion of a nanoscale ceramic fillers incorporated in a resin network. It has modulus of elasticity of (12.77 GPa) which is close to that of dentin (18.5 GPa) and the adhesive resin cement (7.7 GPa) causing better distribution of stresses [(12)].

These findings were in concurrence with the findings of Preis V et al 2015 who found comparable fracture strength of both IPS e.max CAD and ZLS crowns [(18)], and with Weyhrauch M et al 2016 who found that the fracture resistance of the IPS e.max CAD, Vita Suprinity, and Lava ultimate materials was equivalent [(19)]. On the other hand, these results were not in agreement with Elsaka Se et al 2016 who found that ZLS (Vita Suprinity VS) showed enhanced mechanical properties when compared to LD. This was attributed to the incorporation of zirconia filler to the composition of VS which gives it higher fracture toughness, flexural strength, and elastic modulus [(20)].

Regarding the effect of the preparation design, there was no significant effect of the type of the preparation on the fracture resistance of the ceramic occlusal veneers. These results are in concurrence with Clausen JO et al 2010 who found that the design of the finish line (chamfer of straight-bevelled) did not influence the fracture resistance of the ceramic crowns [(21)].

The large standard deviations obtained in this study could be attributed to various factors including that; the extracted teeth although selected carefully however it might contain subclinical flaws or irregularities and morphological variations as well as The presence of premature contact between the inner surface of the restoration and the tooth structure, internal defects as a result of CAD/CAM milling or micro cracks of the restoration, sharp transition from occlusal to axial walls, or bonding to different substrates[10,16,17]. However, these variations are likely to exist in clinical situations as well. Therefore, the range of values can be considered relevant as it was related to actual performance.

Maximum posterior masticatory forces lie in the 600-900 N range [23]. Mean fracture loads for LD (1906 N), RNC (1768 N), and ZLS (1805 N) occlusal veneers in the present study exceeded those values, which indicates that all 3 materials tested can withstand the maximum bite force without fracture.

Most occlusal veneers showed a catastrophic fracture of the teeth, this may be attributed to that the force required to fracture the occlusal veneers might exceed the limit needed to fracture the natural teeth (1668 N). Also, the adhesive bonding might be a contributing factor. In a study by Burke et al 1999 evaluating the fracture resistance of dentin-bonded all ceramic crown; Burke stated that "By employing a varying combination of ceramic and luting/bonding systems, the fracture resistance of teeth restored with dentine bonded crown may be enhanced, but this may be at the expense of catastrophic tooth fracture in a proportion of cases when the fracture occurs [14].

The limitations of this study were the use of human teeth of slightly different dimensions which prevent complete standardization of the restoration form and anatomy, and this study was invitro which could not replicate the oral environment and its effect on loading of the restoration.

Future researches including cyclic loading, fatigue, and bond strengths are required to replicate the entire spectrum of occlusal loading and to get more reliable results. Also, Long-term clinical studies are needed to assess the effect of an oral environment on the strength of the restoration-tooth system. Finally, Studies including occlusal veneers fixed-fixed bridge as a new bridge design which is more feasible and more conservative treatment option are also required.

CONCLUSION

The failure load of CAD/CAM Ceramic and resin nano-ceramic occlusal veneers exceeded the reported range of human masticatory forces. Occlusal veneers made of IPS e.max CAD, Lava Ultimate, and VITA SUPRINITY, are of comparable strength and can be used as an alternative treatment for the severely worn dentition. There was no effect of the preparation designs or the material types on the fracture resistance of occlusal veneers.

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