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Evaluation of Fracture Resistance of CAD-CAM-Fabricated Ceramic Occlusal Veneers with New Preparation Design

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Abstract

The goal of study was to assess the impact of different preparation methods on the fracture resistance of CAD/CAM ceramic occlusal veneers. Twenty-eight occlusal veneer restorations were created using IPS e.max CAD for computer-assisted design and manufacturing. The restorations were later classified into two primary groups based on their preliminary design, with each category consisting of fourteen restorations. Group I (G1) consist of IPS e.max CAD restorations that have been subjected to conventional occlusal veneer preparation and have a butt joint finish line. Group II, commonly referred to as (G2): This category includes IPS e.max CAD restorations with occlusal veneer preparation, which entails a buccal groove. The occlusal veneers were affixed to replicated epoxy dies using G-cem resin cement. Before submitting the samples to failure by applying stress using a computer-controlled materials testing apparatus, they underwent thermocycling and chewing simulations. The data were gathered and subsequently examined utilizing statistical methodologies. There was no significant difference in the fracture resistance between the two groups. The occlusal veneer preparation involved a buccal groove resulted in fracture resistance values that were like those of the traditional preparation. It can be deduced that IPS e.max CAD is a viable choice for occlusal veneer restorations when employing an innovative preparation design.

Keywords: IPS e.max, Fracture Resistance, CAD/CAM, New design, Occlusal Veneer.

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1. Introduction

By utilizing CAD/CAM technology, dental restorations can be designed more efficiently, and the materials used to build them have their physical and mechanical qualities improved. Due to their improved mechanical and physical qualities, ceramic restorations can survive the forces put on the molars during normal functioning, making them suitable for both front and back teeth in current times. Nevertheless, when subjected to stress, most of these materials exhibit brittleness, which ultimately results in fracture propagation and failure [1-2]. The effectiveness of the IPS e.max CAD ceramic material, which is commonly used in subtractive CAD/CAM processes, was examined in this study. The remarkable aesthetic qualities, strong durability, precise precision, and reliable attachment to tooth structure of this material have earned it a stellar reputation. The study included both resin cements and ceramics, which were chosen for their suitability for dental applications and their availability in the market. Although some dentists have begun to select conservatism because to the availability of CAD/CAM technology and contemporary restorations, preserving tooth structure remains a challenging and time-consuming process [3-4]. In addition to avoiding tooth pain, this technique preserves pulp life and tooth architecture [5]. The hypothesis of this research is that CAD/CAM occlusal veneers' mechanical properties could be improved by making design modifications to the veneers design.

2. Materials and methods

The materials used were low translucency (IPS e.max CAD ceramic blocks in size C14, made in Italy by Ivoclar Vivadent). In addition, 4-MET, phosphoric esters, and polyalkenoate acid were utilized in the G-cem self-adhesive resin cement application. The Tokyo, Japan-based G.c firm makes capsules with the express purpose of being used only once. According to the research, an independent samples T test with a 0.05 significance level would have 80% power with 14 samples in each group. Each group consisted of fourteen samples for our experiment.

2.1. Teeth preparation

The two maxillary molar teeth were obtained from Minia University's Faculty of Dentistry's outpatient clinics. Their average occlusal dimension is 6mm x 5mm. There is no decay, fillings, or fractures in the newly extracted molars. For the purpose of removing any superficial debris, the teeth were cleaned using ultrasonic technology. After that, they can be utilized to create samples.

The specimen's roots were nicked using a tapered stone from (Komet Dental, Germany), which had a rounded end, to improve the mechanical interaction with the mold. Following the manufacturer's instructions, chemical-cured acrylic resin (sometimes called cold cure acrylic resin or Acrostone) was made using Egyptian raw materials. When the dough was of the proper consistency, it was transferred to a specially designed Teflon mold for the purpose. The height and diameter of the mold were both 2.5 cm. The Egyptian lab at Minia University that specializes in fixed prosthodontics made the Teflon mold. Using a stainless-steel paralleling equipment that was custom-made, the tooth roots were placed into the center of the mold, 2 mm below the cement enamel junction. The tooth had to be perfectly aligned with the center of the mold, therefore this was done. A stainless-steel metallic wax carver (Pakistan, Miltex Co) quickly removed the surplus acrylic resin. The Teflon mold was carefully removed after the polymerization of the acrylic resin was complete [6-7]. A wheel cutting stone made by (illustrious Lemgo, Germany-based company Komet Dental) was used to uniformly reduce the occlusal height of both molars. The purpose of this process was to establish a standard for consistent and reliable preparation. The molar teeth were meticulously crafted by hand with a spherical bur and diamond wheel cutting stones measuring 14 in size. In order to prevent the operation from producing too much heat, water cooling was used. The high-speed handpiece, manufactured by (W&H Dental Work of Burmoos, Austria) used a pressure of 2.6Mpa. Making indices using condensation silicone rubber base (Speedix putty Ivoclar Vivadent, Liechtenstein) before beginning the preparation to maintain a uniform thickness. The putty paste and catalyst were mixed by hand to create the silicone indices, following the directions on the packaging. The mixture was then transferred to a stainless-steel tray that had been constructed to order with holes in it by (Fixed Prosthodontic Department at Minia University, Egypt). After the impression was configured, the index was removed. Initially, a periodontal probe (Miltex, stainless steel, Pakistan) was used to measure the occlusal surface preparation at the central fossa, and the result was found to be 1.0 mm. By utilizing a rubber base index, the thickness reductions were subsequently confirmed. A butt joint preparation, or flat occlusal reduction in the absence of a clearly defined finish line, was the part of the preparation that was necessary (Figure 1 & 2).

2.2. Dies construction

A rubber base material (Speedix, made by Ivoclar VivaDent of Liechtenstein) was mixed by hand according to the manufacturer's instructions to generate twenty-eight teeth. After the prepared tooth was placed into the tray, an impression was loaded on it. Then it was removed from the prepared tooth once it hardened. The epoxy resin (kemapoxy 150, Egypt) which was used to make the die. The full hardening and preservation of its shape could only be achieved after 48 hours. The dies were taken out of the impression and polished with a low-speed straight hand piece that was equipped with a cylindrical finishing stone (Komet Dental. Gabr. B raseler GmbH& Co.KG of Trophagener Weg, Lemgo, Germany). After that, a modern electric brush (Miltex, Stainless steel, Pakistan) and pumice (Dental Lab Pumice, Dentsply, USA) were used to polish the dies. Die preparation for occlusal veneer production was completed by following these guidelines. This was repeated to generate twenty-eight samples.

2.3. Occlusal veneer constructions

Design, milling, and crystallization were all steps in the manufacturing of the occlusal veneers. Every step of the production process for the occlusal veneers (IPS e.max CAD) was carried out according to the manufacturer's guidelines. (Dentsply Sirona's Cerec Omnicam camera system) was used to consecutively capture the epoxy dies without powder. All occlusal veneers were made using the same standard technique with the use of software. First, the restoration type and design were chosen. Prior to imaging, the Cerec Omnicam was used to record the preparation by positioning the camera on the occlusal surface. A measurement of 30μm was chosen for the internal gap, which indicates the distance between the veneers internal surface and the epoxy resin for the cement. On the other hand, the marginal gap was carefully calibrated to 0 μm [8-9]. The next step in starting the milling process was to select the milling position symbol. In the Ivoclar VivaDent program at P310 oven, the IPS e.max CAD ceramic occlusal veneers crystallized. At 403°C, the crystallization process began in the sealed oven. The temperature rose to 770°C, the crucial ignition point, with a linear rise of 60°C/min. For thirty minutes, the temperature was set to fire. The veneers were finally taken out of the oven when its temperature was equal to that of the room. Following the manufacturer-provided instructions, the teeth were fixed to the prepared teeth using G-cem resin cement, a self-adhesive resin cement. According to the specifications of the custom-made loading device (fixed prosthodontic department at Minia University, Egypt) 6 N of load was applied to the restoration after cementation [22]. After the excess material was pressed out using a bond brush (micro brush, China) and a light-cured device (woodpecker, I LED, China) for 40 seconds, the process was completed. The samples were first put through thermocycling and chewing simulation before being tested for fracture resistance using the universal testing machine (UTM). Data gathering, organized, and statistical analyzed. The IPS e.max CAD occlusal veneers were treated for 90 seconds with a 9.5% hydrofluoric acid gel (BISCO-Schaumburg U.S.A.) before cementation by using a dental chair (Roson co, China) used an air spray to dry the veneers after rinsing them thoroughly during the etching process. The veneers were subsequently treated with a silane coupling agent (BISCO-Schaumburg U.S.A.) and allowed to set undisturbed for 30 seconds post-treatment. Following the manufacturer-provided instructions, the veneers were subsequently dried using an air syringe. A thorough cleaning and drying procedure was performed on the epoxy dies. The self-adhesive resin cement G-cem was applied according to the manufacturer's instructions. As soon as the occlusal veneers were fully bonded, the tested samples were prepared. A 24-hour immersion in distilled water at 37°C was performed on the samples prior to thermocycling. Following the guidelines set out by the International Organization for Standardization (ISO/TS 11405), the thermocycling made use of 1000 cycles, which is roughly equal to two years of clinical use.

Robota, an automated thermal cycle system manufactured by BILGE in Turkey was used for 25-second immersions in each water bath (Figure 3). Following that, the samples were placed into the chewing simulator apparatus. Data was collected, organized into tables, and analyzed statistically.

2.4. Fracture Resistance test

Attaching the samples to the testing device's bottom fixed compartment was done using screws. A metallic rod with a spherical tip (6.4 mm in diameter) attached to the top movable part of the testing device was used to apply an occlusal compressive force in order to conduct the fracture test. The machine was set to run at a crosshead velocity of 1mm/min and a layer of tin foil was inserted to disperse stress evenly and prevent localized force spikes from being transmitted. Using computer software (Bluehill Lite Software Instron® Instruments), a significant decrease in the load-deflection curve was quantified and an audible crack was used to detect the load failure. Newtons were used to quantify the fracture load.

2.5. Mode of Failure

Samples from each test group were examined under a USB digital microscope (U500x Digital Microscope, Guangdong, China) set to x35 magnification after the fracture resistance test had been run. The images were subsequently captured and sent to an IBM PC running the Image-tool application (Image J 1.43U, National Institute of Health, USA). Using the classification method described in reference [25-26], this study aimed to determine the failure mode pattern.

2.6. Image acquisition system

Image acquisition system used to capture the images is as follows:

1. A digital camera with a resolution of 3 Mega Pixels, the U500x Digital Microscope is made in Guangdong, China. Keeping it 2.5 cm from the samples, it is positioned vertically. The light source forms an angle of approximately 90 degrees with respect to the long axis.
2. A total of eight controllable LED lights were used to provide the necessary illumination. A color index of almost 95% was achieved using the LEDs.
3. The photographs were captured using an IBM compatible personal computer at a fixed magnification of 35X, with the highest possible resolution of 2272 × 1704 pixels. The resolution of each image captured by the photographs was 1280 × 1024 pixels.

3. Results

Both groups showed similar levels of resistance to fractures. After being subjected to thermomechanical stress, the fracture strength reduced.

3.1. Fracture resistance Test

When utilizing IPS e.max CAD with occlusal veneer preparation with a buccal groove (G2), the fracture resistance was reduced to (1935.17 N), as shown in Table 1. After using IPS e.max CAD with conventional occlusal veneer preparation (G1), the resistance was recorded (2327.21 N). According to these findings, none of the groups that were tested showed a statistically significant difference.

4. Discussion

Typically, a force ranging from 100N to 200N was found posteriorly in the oral cavity at the occlusal surface of molars [10]. However, the amount of force can increase to 965N in case of a sudden bite on a hard foreign item or due to physical harm. According to the findings of this study, a fracture strength of more than 1000N is critical for a positive clinical result [11-12]. Full coverage all-ceramic crowns with an occlusal thickness of 1.5-2mm can withstand a maximum stress of 771-1183 N without destructing teeth, according to studies by Pallis et al., (2004) and Kikuchi et al., (1997). Their results show that the fracture strength is higher than the 585–880 N unit range that has been measured for forces applied during chewing [11-12]. The average occlusal force applied to samples restored with IPS e.max CAD ranges from 100 N to 200 N in the posterior molar area and can exceed 965 N in instances of a forceful bite, according to Chen et al., (2014) [10]. For the entire therapeutic time, a force of at least 1000 Newtons is required. The highest forces exerted during chewing in the back of the mouth might vary between 200 and 450 Newtons, according to Bates et al. (1976). Nevertheless, these forces can reach an incredible 800N in bruxism sufferers [13]. Monticelli et al. (2008) and Cantoro (2009) discovered that RelyX ARC and G-Cem exhibited comparable binding strengths to dentin. Consistent with previous research, G-Cem's bonding ability may be linked to its capacity to chemically interact with the smear layer on the dentin surface [14-15]. In addition, Gonçalves et al. (2017) found that using G-Cem resin cement significantly increased the adhesion strength [16]. There has been a substantial improvement in the mechanical and optical qualities of the IPS e.max Press material [17,20]. Impressive strength was discovered by Sieper et al. (2017) in lithium disilicate. The 1 mm thick lithium disilicate (CAD/CAM) material has a high load-bearing capacity due to its mean fracture force of 2,535 N [18]. Both Mohey (2018) and Kim et al. (2022) found that thermomechanical stress reduced the fracture resistance of IPS e-max Cad [25-26]. Researchers Magne et al. (2012) found that using thin composite resin occlusal veneers reduced the risk of fracture. To treat severe erosive lesions in the back teeth, researchers have shown that ultra-thin lithium disilicate (e.max CAD) occlusal veneers are a less invasive option than traditional onlays and full coverage crowns. The results of this investigation agree with this finding [19]. Occlusal veneers' fracture resistance is unaffected by ceramic material type or preparation design, according to research by Mostafa et al. (2023) [21]. All the CAD/CAM materials tested, including vita enamic and lithium disilicate, exhibited fracture loads higher than the minimum strength required for posterior restorations, and this was true regardless of the specific preparation methods used. A substantially greater value was shown by the 0.5 mm thick IPS e.max CAD veneers. When it came to the maxillary premolar region and IPS, all the evaluated occlusal veneers showed fracture resistance values that were within the usual range. For occlusal veneers that require extra care and long-term durability, e.max CAD ceramic is the choice.

Figure 1: Shows a traditional occlusal veneer reduction.

Figure 2: showed occlusal veneer preparation with a buccal groove.

Figure 3: Robota, an automated thermal cycle system.

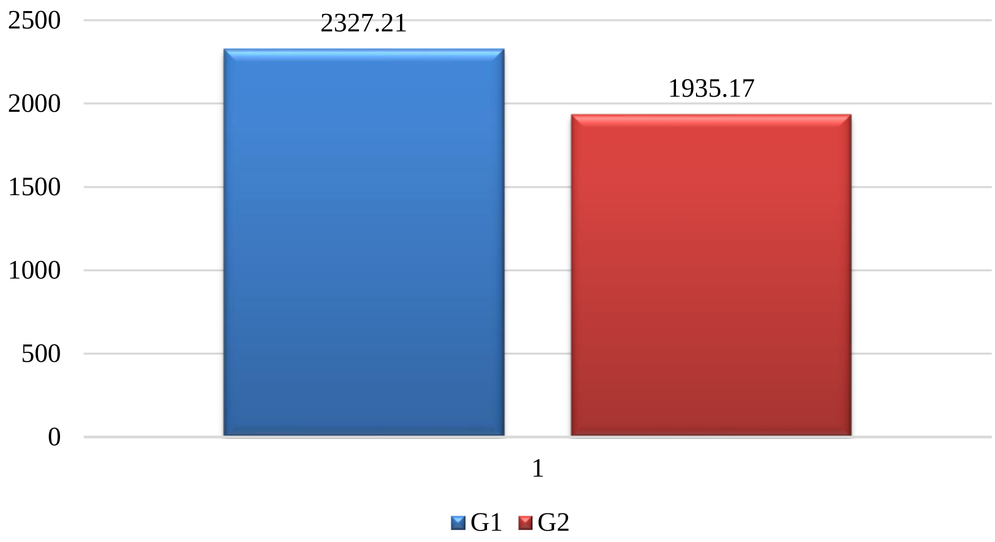

Figure 4: Comparison of fracture resistance between the two groups.

Figure 5: Group I Repairable; Cracked veneer only.

Figure 6: Group II Repairable; Cracked veneer only.

Table 1: Classification of failure modes.

Class I	Cracked restoration
Class II	Fractured within the restoration
Class III	Adhesive fracture between the restoration and the tooth
Class IV	Longitudinal fracture of the restoration and tooth

Table 2: Mode of failure.

Name	**Mode of failure**
Gr_1	Cracked restoration
Gr_2	

Class I failure mode was identified by Guess et al., (2013) and Al-Akhali, et al. (2019), it indicates a repairable cracked restoration for Group I & II [23-24]. Although the fracture strength increased with the new design during thermocycling and chewing simulations, there was no significant difference between the two groups despite decreasing fracture values with the new design, so the hypothesis of this research is rejected.

5. Conclusions

With the limitations of this study in mind:

1. IPS e.max CAD could be used as occlusal veneer material Because their flexural strength values remain within the clinically acceptable range even when subjected to thermomechanical stress.
2. The results from the occlusal veneer preparation, which included making a buccal groove, were like those from the conventional preparation in fracture resistance.

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