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Original article

Fracture strength testing of crowns made of CAD/CAM composite resins

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ABSTRACT

Purpose: The purpose of this study was to ascertain whether computer aided design/computer aided manufacturing (CAD/CAM) composite resin crowns have sufficient strength to withstand the bite force of the molar teeth. The null hypothesis was that the fracture strength of CAD/CAM composite resin crowns is lower than the average maximum bite force of the molar tooth.
Methods: The crowns, which shape is the right maxillary first molar, were fabricated using four CAD/CAM blanks made of composite resins (Block HC: HC, KZR-CAD HR: HR, KZR-CAD HR2: HR2, Avencia Block: AVE) and one CAD/CAM blank made of lithium disilicate glass-ceramic (IPS e.max CAD: IPS), which was used as a control. Fracture strength of fabricated crowns bonded to metal abutment and biaxial flexural strength of the materials were evaluated.
Results: The results of fracture strength test and biaxial flexural strength test showed different tendencies. The fracture strength of CAD/CAM composite resin crowns except HC ranged from 3.3 kN to 3.9 kN, and was similar to that of IPS (3.3 kN). In contrast, biaxial flexural strength of CAD/CAM composite resins ranged from 175 MPa to 247 MPa, and was significantly lower than that of IPS (360 MPa).
Conclusions: All CAD/CAM composite resin crowns studied presented about 3–4 times higher fracture strength than the average maximum bite force of the molar tooth (700–900 N), which result leads to the conclusion that CAD/CAM composite resin crowns would have sufficient strength to withstand the bite force of the molar teeth.

1. Introduction

In dentistry, computer aided design/computer aided manufacturing (CAD/CAM) technology has advanced rapidly since 1987 when Rekow et al. reported their pioneering work in an automated design system for crowns [1,2]. CAD/CAM fabrication of dental restorations simplifies handling and is less labour intensive, increasing efficiency at a reduced cost [2]. Thus, the CAD/CAM technology has been applied to various materials used for dental prosthetics, mainly resins and ceramics, and is expected to advance further. An example of CAD/CAM technology applied in clinical dentistry is crowns made of composite resins. CAD/CAM composite resin crowns are produced by compressing and heat-curing composite resins into blocks, and then fabricating these into crowns using the CAD/CAM technology. In Japan, these crowns have been used widely in clinical practice since 2014. However, there are some concerns over the strength among CAD/CAM composite resin crowns when used for molars because of an insufficient number of studies investigating their strength [3], necessitating careful investigation of fracture strength in CAD/CAM composite resin crowns.

When evaluating the indications for novel materials, it is important to elucidate the properties of these materials such as mechanical properties and long-term durability under intraoral conditions. On the other hand, it is also important to investigate these properties of new materials in vitro testing [4]. Conventionally, the mechanical properties of ceramic and resin materials are evaluated using a flexural strength test and other basic tests specified by the international organization for standardization (ISO). The most common flexural test methods used are the 3-point and 4-point bending tests, which have a significant drawback because of difficulties in eliminating undesirable edge failures [5]. As a result, the biaxial flexural test is frequently used to determine the fracture characteristics of ceramic materials. However, these flexural tests would be insufficient to evaluate mechanical properties because the morphology of test materials and the way loads are applied vary greatly between laboratory settings and actual intraoral conditions. On the other hand, many studies

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evaluating the fracture strength of crown-shaped specimens have been reported [6–8], though the methods used in those studies have also various problems. When using a conventional build-up method, it is extremely difficult for even skilled technicians to reproduce multiple crown-shaped specimens with complex clinical morphologies, such as pits and fissures, resulting that simple forms are often used in fracture strength testing, in which the occlusal surfaces of the preparations and ceramic restorations were flat to assist in the ease of fabrication and testing and did not replicate the cuspal inclines found clinically [9–11]. However, their shapes differ greatly from those for actual clinical application. In contrast, the CAD/CAM technology enables the reproduction of crowns with complex morphologies even from different materials.

The purpose of this study was to ascertain whether CAD/CAM composite resin crowns have sufficient strength to withstand the bite force of the molar teeth. The null hypothesis was that the fracture strength of CAD/CAM composite resin crowns is lower than the average maximum bite force of the molar tooth.

2. Materials and methods

2.1. Materials

Four types of composite resins were used as CAD/CAM restoration materials: Shofu Block HC (HC) (Shofu Inc., Kyoto, Japan), KZR-CAD HR (KZR) and HR2 (KZR2) (Yamamoto precious metal Co., Ltd., Osaka, Japan), and Katana Avencia block (AVE) (Kuraray noritake dental Inc., Tokyo, Japan). IPS e.max CAD (IPS) (Ivoclar vivadent AG, Schaan, Liechtenstein) a lithium disilicate glass-ceramic CAD/CAM material that has been used in clinical settings, was used as a control (Table 1).

2.2. Fracture strength testing of CAD/CAM crowns

Abutments made of stainless steel (SUS304) with an occlusal reduction of 1.5–2.0 mm and a heavy chamfer edge were prepared as a base for fracture strength testing (Fig. 1A). The abutment taper angle was 7°, and all the corners were rounded. Abutments were scanned using a three-dimensional digital scanner (Katana System, Kuraray noritake dental Inc.), and the scanned image was used to design a crown with the shape of the right maxillary first molar, and then the three-dimensional (3D) model of the crown was obtained in the stereolithography (STL) file format (Fig. 1B). The cement space was set at 80 μm. Then, we requested the manufacturers of the four types of composite resin blocks to create crowns using their materials from the STL data. After adjusting the shape according to the universal protocol, the crowns were polished using the Abbott-Robinson bristle brush and abrasives (C & B diamond abrasive, Yamamoto precious metal Co., Ltd.). Using a CAD/CAM system (Ceramill motion 2, Amann Girrbachh, AG, Koblach, Austria), IPS was milled to a crown using the same STL data as the other crowns according to the universal protocol, followed by heating at 850 °C for 25 min in a furnace (Phoenix quick cool, Dentsply ceramco, Burlington, NJ) for crystallization. After cooling to room temperature, the IPS crown was polished using the Abbott-Robinson bristle brush and the same abrasives. The inner surface of each crown was subjected to sandblast treatment (0.1 MPa) with alumina particles and then to ultrasonic cleaning using distilled water in an ultrasonic bath for 10 min. The crowns were immersed in physiological saline (Otsuka pharmaceutical Co., Tokyo, Japan) and kept for 24 h at 37 °C in a constant temperature oven (DNE400, Yamato scientific Co., Tokyo, Japan).

After applying a universal primer (Tokuyama dental, Tokyo, Japan) to the inner surface of each crown and abutment, they were bonded using an adhesive resin cement (Estecem Automix, Tokuyama dental). The occlusal, mesial, distal, buccal, and palatal surfaces of the crowns were irradiated (VALO LED Curing Light, Ultradent products, Inc., South Jordan, UT, USA) for 20 s each, and the crowns were kept at 37 °C for 24 h for hardening (Fig. 1C).

To test the strength of the five kinds of crowns ($n = 10$ each), 3 points near the central pit on the occlusal surface of each crown which was bonded to an abutment were selected as loading points (Fig. 1D), and a clear polyethylene sheet (thickness, 0.04 mm) and then a 5.0 mm stainless steel ball were placed on the occlusal surface (Fig. 1E). Using a universal testing machine (model 4481, Instron Corp., Norwood, MA, USA), compressive loads were applied in the direction of the tooth axis at a crosshead speed of 0.5 mm/min until the crown broke down, and then the load at fracture was recorded.

2.3. Biaxial flexural strength testing of CAD/CAM materials

The IsoMet Low Speed Saw (Buehler Ltd., Lake Bluff, IL, USA) was used to cut each resin material into plates of the same length, and the plates were formed into round specimens 12 mm in diameter. Then, the specimens were polished to a mirror-finish with a final thickness of 1.0 ± 0.2 mm using the Ecomet III Grinder-Polisher (Buehler Ltd.) and alumina powder (0.3 μm).

The biaxial flexural strength of the specimens ($n = 10$ each) was measured using a universal testing machine (model 4481, Instron Corp.) in accordance with ISO specifications (6872:2015,

Table 1
Materials used in this study.

Material	Code	Manufacturer	Composition	Lot no.
Shofu block HC	HC	Shofu Inc., Kyoto, Japan	UDMA, TEGDMA, silica powder, micro fumed silica, and zirconium silicate	061401
KZR-CAD HR	KZR	Yamamoto precious metal Co., Ltd., Osaka, Japan	UDMA, DEGDMA, SiO_2–Al_2O_3–ZrO_2 (200–600 nm), and SiO_2 (20 nm, 100 nm)	01071428
KZR-CAD HR2	KZR2	Yamamoto precious metal Co., Ltd., Osaka, Japan	UDMA, DEGDMA, SiO_2–Al_2O_3–ZrO_2 (200–600 nm), SiO_2 (20 nm, 100 nm), and fluorine sustained-release filler (700 nm)	01051508
Katana avencia block	AVE	Kuraray noritake dental, Tokyo, Japan	Methacrylate monomer, silica (20 nm), and alminum oxide (40 nm)	000062
IPS e.max CAD	IPS	Ivoclar vivadent AG, Schaan, Liechtenstein	Lithium disilicate glass-ceramic	T33940

UDMA, urethane dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; DEGDMA, diethylene glycol dimethacrylate. Composition of the materials examined as published by manufacturers.

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