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Features of fracture of prosthetic tooth-endocrown constructions by means of acoustic emission analysis

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ABSTRACT

Objective. The study aims at comparing the fracture resistance of different restorative materials used in dental endocrown restorations and respective endocrown restorations under a quasi-static compressive load using acoustic emission (AE) method.

Methods. Five restorative materials were used in this study. The restorative materials were manufactured into discs 13 mm in diameter and 5 mm thick, which were then divided into 5 groups and included into Type 1: Group B: zirconium dioxide (Prettau zirconia); Group C: ceramics (IPS e.max Press); Group D: metal ceramics (GC Initial MC + Nicrallium N2 BCS); Group E: composite resin (Nano Q); Group F: luting cement (RelyX^{TM} U200). Twenty-five extracted human molars were divided into 5 groups and included into Type 2: Group A: control, no restoration; Group BE: restored by zirconium dioxide endocrowns; Group CE: restored by ceramic endocrowns; Group DE: restored by metal ceramic endocrowns; Group EE: restored by composite resin endocrowns. An increasing load was applied to the center of the samples with a hard steel ball until a fracture occurred. The loading rate was 0.12 mm/min. An AE system was used to monitor the fracture of the samples. The load corresponding to the first AE event and the final fracture load were used to evaluate the fracture resistance of the restored teeth. The data were analyzed using ANOVA and Tukey's post hot test ($\alpha = 0.05$).

Results. A lower threshold of 220 μV was selected to exclude spurious background signals. For the initial fracture load of Type 1 samples, Group F (0.029 kN) < Group E (0.039 kN) < Group D (0.056 kN) < Group C (0.253 kN) < Group B (intact). The same trend was found for the final fracture load, i.e., Group F (1.289 kN) < Group E (1.735 kN) < Group D (3.362 kN) < Group C

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(6.449 kN) < Group B (intact). For the initial and final fracture load, statistically significant differences ($p < 0.05$) were found between group C and the others groups. For the initial fracture load of Type 2 samples, Group EE (0.069 kN) < Group DE (0.072 kN) < Group CE (0.148 kN) < Group BE (2.511 kN). For the final fracture load, Group EE (1.533 kN) < Group CE (2.726 kN) < Group BE (3.082 kN) < Group DE (3.320 kN). The initial fracture load of the ceramic samples is somewhat higher than that for the endocrown restorations with the endocrowns made of this material (0.253 and 0.148 kN, respectively). At the same time, for the metal ceramic and composite resin samples, the initial fracture loads are somewhat lower than in case of compression of the endocrown restorations with the endocrowns made of these materials (0.056 and 0.072 kN; 0.039 and 0.069 kN, respectively). The final fracture load of all the samples of the dental materials exceeds the strength of the respective endocrown restorations. The final fracture loads of the endocrown restorations with zirconium dioxide and ceramic endocrowns (3.082 and 2.726 kN, respectively) are significantly lower than the final fracture load of the respective endocrown materials (intact and 6.449 kN, respectively).

Significance. Dental restorations should be made of high-strength materials. Zirconia displayed the highest fracture strength, while composite resin had the lowest fracture strength out of the materials used for the endocrowns. For teeth restored with endocrowns, the use of metal ceramics as endocrown material may lower the risk of failure during clinical use.

1. Introduction

Prosthetic treatment of damaged teeth aims at restoring all their parameters, both esthetic and functional. Denture technologies are constantly developing and at present there are numerous means for an effective, complete or partial, restoration of lost tooth crowns. Pissis [1] proposed the endocrowns as an alternative crown for molars, depending on the availability of the remaining tooth structure. The term 'endocrown' was first defined by Bindl and Mörmann [2] as a monolithic ceramic bonded construction fixed to the tooth structure by adhesive material. The endocrown provides a proper adhesion of a ceramic restoration with minimal invasion into the root canal, which is an important factor for preserving the tooth. As compared to the conventional methods, endocrowns offer good esthetics, better mechanical performance, and lower costs and clinic time [3].

Preservation of the tooth structure in prosthetic treatment is important both for the tooth protection from breaking during chewing and for the endurance. On the other hand, loss of structural integrity leads to an increased risk of the crown fracture. Thus, choice of the type of restoration and restorative materials has a considerable influence on the efficacy and duration of endodontic treatment [4–11].

Endocrowns are made of different materials, including feldspathic ceramics and ceramics reinforced with lithium disilicate, hybrid resin composites and the newest CAD/CAM ceramic and resin composite blocks. According to the literature, mechanical properties and fracture development in endocrown restorations were studied using mainly mechanical tests [12–18] or finite element analysis [19–23].

Many authors have evaluated the fracture strength and failure modes of endocrowns in comparison with other types of restorations. Biacchi et al. [12] investigated the fracture strength of endocrowns and post constructions. Rocca et al. [13] found that the modification of CAD–CAM resin nano ceramic restorations for upper premolars with restorative resin for esthetic purposes has no influence on their fatigue resistance except when monolithic crowns are modified at their occlusal surface. Using a compressive load, Bankoğlu et al. [14] studied the fracture strength and failure modes of endocrowns, zirconia post, and fiber post supported restorations. Bindl et al. [15] studied the strength and fracture pattern of monolithic posterior crowns fabricated from three types of block ceramics — lithium disilicate glass, leucite glass and feldspathic ceramics using CEREC 3 CAD/CAM each were zinc-phosphate cemented and adhesively cemented on resin-based composite dies. El-Damanhoury et al. [16] evaluated the microleakage, fracture resistance, and failure modes of three types of CAD/CAM fabricated restorations when submitted to an oblique compressive force. Lise et al. [17] evaluated the effect of endocrown design and CAD/CAM material type (composite or lithium disilicate glass ceramics) on the load-to-failure of endodontically treated premolars in absence of any ferrule. Gresnigt et al. [18] studied the effect of axial and lateral forces on the strength of endocrowns made of lithium disilicate glass ceramic and multiphase resin composite. Failure type and location after debonding/fracture were classified.

Using 2D finite element models of a real tooth restored by endodontic methodologies, Riera i Jorrin [19] investigated the risk of fracture and debonding in different restorations. Using 3D finite element analysis, Dejak and Młotkowski [20] compared equivalent stresses in molars restored with endocrowns as well as posts and cores during masticatory simulation; Zhu et al. [21] studied the effect of tooth preparation and material type on the stress distribution of endodontically treated teeth restored with endocrowns; Hasan et al. [22] evaluated the biomechanical behavior of adhesive endocrowns and the influence of their design on the restoration prognosis when four loading positions are applied from the restoration-tooth junction; Chen et al. [23] studied the influence of various materials (composite resin, ceramage and ceramics) on the