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Probability of survival of implant-supported metal ceramic and CAD/CAM resin nanoceramic crowns

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ABSTRACT

Objectives. To evaluate the probability of survival and failure modes of implant-supported resin nanoceramic relative to metal-ceramic crowns.

Methods. Resin nanoceramic molar crowns (LU) (Lava Ultimate, 3M ESPE, USA) were milled and metal-ceramic (MC) (Co–Cr alloy, Wirobond C+, Bego, USA) with identical anatomy were fabricated ($n = 21$). The metal coping and a burnout-resin veneer were created by CAD/CAM, using an abutment (Stealth-abutment, Bicon LLC, USA) and a milled crown from the LU group as models for porcelain hot-pressing (GC-Initial IQ-Press, GC, USA). Crowns were cemented, the implants ($n = 42$, Bicon) embedded in acrylic-resin for mechanical testing, and subjected to single-load to fracture (SLF, $n = 3$ each) for determination of step-stress profiles for accelerated-life testing in water ($n = 18$ each). Weibull curves (50,000 cycles at 200N, 90% CI) were plotted. Weibull modulus (m) and characteristic strength (η) were calculated and a contour plot used (m versus η) for determining differences between groups. Fractography was performed in SEM and polarized-light microscopy.

Results. SLF mean values were 1871N (±54.03) for MC and 1748N (±50.71) for LU. Beta values were 0.11 for MC and 0.49 for LU. Weibull modulus was 9.56 and $\eta = 1038.8$N for LU, and $m = 4.57$ and $\eta = 945.42$N for MC ($p > 0.10$). Probability of survival (50,000 and 100,000 cycles at 200 and 300N) was 100% for LU and 99% for MC. Failures were cohesive within LU. In MC crowns, porcelain veneer fractures frequently extended to the supporting metal coping.

Conclusion. Probability of survival was not different between crown materials, but failure modes differed.

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Significance. In load bearing regions, similar reliability should be expected for metal ceramics, known as the gold standard, and resin nanoceramic crowns over implants. Failure modes involving porcelain veneer fracture and delamination in MC crowns are less likely to be successfully repaired compared to cohesive failures in resin nanoceramic material.

1. Introduction

Since osseointegration of dental implants is a predictable treatment modality, there is a demand for comprehensive understanding of the main complications of prosthetic designs eventually affecting success rates [1,2]. Increasing efforts have been devoted in attempt to describe differences in prosthetic outcomes for implant-supported reconstructions, for instance, regarding external relative to internal connections, cemented versus screwed prostheses in systematic reviews [3,4] and laboratory studies [5,6]. However, when considering the final prostheses material for implant-supported reconstructions, very few studies have addressed the outcomes of all-ceramic materials which currently are increasingly demanded from both patients and dentists for improved esthetic results.

The use of high-strength ceramics such as stabilized zirconia has gained attention for use as a substructure material, especially for large span reconstructions due to its high mechanical properties [7]. However, long-term clinical studies are virtually exclusive for tooth-supported zirconia-veneered fixed dental prostheses (FDP), and they include a very high variation in results among trials where the main reported complication is fracture of the veneering porcelain [8]. Although clinical results for implant-supported zirconia-veneered single-crowns are sparse [9], the existing studies agree that the main failure is fracture of the veneering porcelain and with a unacceptable variation in failure rates varying from 3% to 24.5% with risks of chipping 3.8 times higher than metal-ceramics [10]. A more recent 5-year prospective study has reported on 42.8% of zirconia-veneered porcelain fracture complications for implant-supported single crowns, which does raise concerns for its indication [11]. Reasons for such high failure rates and ways to diminish them have been extensively presented in the literature and include an array of materials and laboratory handling precautions. In addition, patient-related factors such as the decreased proprioception and lower tactile sensitivity contributes to making implant-supported reconstructions more prone to failure [12].

While future trials reporting the successful use of zirconia-veneered implant-supported reconstructions are warranted, the development of metal free alternatives, such as resin nanoceramic has gained interest also in implant prosthodontics. Resin based materials are claimed to have more resiliency compared to ceramics resulting in improved dampening from occlusal forces [13,14] to be more repair-friendly should chipping occur, and easier to grind during computer-assisted machine/computer-assisted manufacture (CAD/CAM) process or during occlusal adjustments.

Previous research has demonstrated that several composites directly bonded to titanium abutments as molar crowns (IAC® – integrated abutment crowns) presented similar single load to fracture (SLF) values compared to metal ceramic crowns (MC) [15]. Considering that fatigue plays a more relevant role in simulating clinical failures [16], recent studies have evaluated the use of hand-layered indirect composites for implant-supported molar crowns and found promising probability of survival (reliability) when tested under fatigue [17,18]. Given that flaws, such as voids, are inherently introduced when an indirect composite is hand-layered, pressed blocks of resin nanoceramics have been developed for milling through the CAD/CAM process from several companies in attempt to further improve them from a fatigue resistance perspective.

Considering metal ceramic as the gold standard for comparisons, this study sought to investigate the reliability and failure mode of MC for implant-supported molar crowns compared to CAD/CAM fabricated resin nanoceramic. Our tested null hypothesis was that there would be no difference in probability of survival or failure modes when subjected to step-stress accelerated life testing in water.

2. Materials and methods

2.1. *Crown fabrication*

Forty-two Ti-6Al-4V abutments (Stealth abutments, shouldered, 3 mm well, 5 mm diameter, Bicon LLC, Boston, MA, USA) were selected for the study and divided in two groups ($n = 21$ each) to support metal ceramic (MC) or Lava Ultimate (LU) (Lava Ultimate, 3M ESPE, St. Paul, MN, USA) maxillary first molar crowns. A waxed model maxillary first molar crown was replicated on an E4D Dentist CAD/CAM system (D4D Technologies, Richardson, TX). Crowns were milled from Lava Ultimate blocks ($n = 21$, shade A3, 3M ESPE) in an E4D mill (3M ESPE), polished with diamond paste and bristle brush, then buffed to a high gloss with a cotton buff. The bonding surface of each Lava Ultimate crown was sandblasted with a 240 mesh alumina (Ney-Brasive™ J.M. Ney Co., Bloomfield, CT, USA). Crowns were cleaned by sonicating in ethanol, air dried, and their intaglio surface primed with RelyX Ceramic Primer (3M ESPE) applied with a fibertip brush, then dried with compressed air.

An anatomic metal coping (Fig. 1) with a 360° collar and veneer top were designed and exported as .STL files for fabrication. Twenty-one metal copings were made via selective laser melting from non-precious cobalt–chromium dental alloy (Wirobond® C+, Bego USA, Lincoln, RI, USA). Veneer tops for lost-wax investment and hot-pressing were made via wax printing (BeCe® Wax-Up material, Bego USA). An opaque layer