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Research Paper

The impact of luting agents and stiffness of implant-abutments on marginal adaptation, chipping, and fracture resistance of zirconia crowns

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ABSTRACT

Objectives: This *in vitro* study evaluated the impact of cements and implant analogs with different e-moduli on marginal adaptation, chipping, and the fracture resistance of zirconia crowns.

Methods: 80 crowns (Cercon, DeguDent) were manufactured for 40 polyoxymethylene (POM) and 40 titanium (Ti) one-piece implant analogs and divided into 10 groups: A, zinc oxide phosphate (Hoffmann's Cement, Richter&Hoffmann, Berlin, D); B, zinc oxide eugenol (Temp Bond, KerrHawe, Bioggio, CH); C, resin (Variolink II, Ivoclar-Vivadent, Schaan, FL); D, zinc oxide without eugenol (Temp Bond NE, KerrHawe, Bioggio, CH); E, glass ionomer (Ketac Cem, 3M ESPE, Seefeld, D). All samples were thermally mechanically loaded ($1.2 \times 10(6) \times 50$ N; $3000 \times 5\,^{\circ}C/55\,^{\circ}C$). Marginal adaptation was semiquantitatively evaluated before and after ageing with a scanning electron microscope. After ageing, intact samples underwent a fracture resistance test.

Results: The best sealed margins before ageing were achieved with resin and zinc oxide cement and with resin after ageing. Zinc oxide samples showed the most discontinuously sealed margins after ageing and the difference between POM and Ti samples was significant only for zinc oxide. The numbers of samples failing during TCML were as follows: A(Ti − POM) = 0 − 1; B(Ti − POM) = 0 − 5; C(Ti − POM) = 1/1; D(Ti − POM) = 2 − 2; E (Ti − POM) = 0 − 2. Fracture resistance test [N]: A(Ti − POM) = 1181 − 801; B(Ti − POM) = 1469 − 1517; C(Ti − POM) = 1704 − 1408; D(Ti − POM) = 1992 − 883; E (Ti − POM) = 2750 − 1015.

Conclusions: TCML reduced the number of perfectly sealed samples and increased the

Abbreviations: Ti, titanium; POM, polyoxymethylene; PMMA, polymethylenemethacrylat; TCML, thermo-cycling and mechanical load; SEM, scanning electron microscope

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number of chipped samples cemented onto POM implants with zinc oxide. This study could not show any significant impact on the fracture resistance of zirconia when different cements and implant analogs were used.

1. Introduction

Veneer chipping or delamination of zirconia-based restorations have been frequently discussed in recent literature reports. Kollar et al. found a higher risk of chipping or facing failures for implant crowns than for crowns on human teeth (2008). Under occlusal load, zirconia-based reconstructions are subjected to bending or stretching forces originating from elastic or plastic deformation of the foundation. Sources of any deformation of the foundation may be the dental luting agent as well as the abutment. Dental implants and their abutments are considered to be stiff and stable foundations; hence deformation of the luting agent may be the source of stress for all-ceramic restorations under occlusal load (Lu et al., 2013). On the other hand, occlusal load absorption could be advantageous for cements or abutments to develop more elastic properties. To show the impact of the luting agent or the abutment on veneering failure, we used stiff titanium implant analogs as well as "elastic" polyoxymethylene implant analogs to determine the risk of veneer chipping and to calculate fracture resistance after thermal cycling and mechanical loading representing oral service. Both types of implant analogs were combined with five different luting agents consisting of cements with different mechanical properties under load. Zinc oxide phosphate and glass ionomer have low compressive strength and are brittle in comparison to resin-based composite cements such as RelyX Unicem®, Variolink II®, or Panavia® (Behr, 2003). Under load, bending or elastic deformations of these cements are expected to be less than those of zinc oxide phosphate or glass ionomer. A provisional type of cement, such as zinc oxide eugenol, was added to the cements because many dentists prefer the retrievability of restorations luted onto dental implants (Behr, 2007; Behr et al., 2009). The mechanical properties of provisional cements are poor. Therefore, even zirconia restorations are expected to show a higher rate of veneer chipping or failure than restorations luted with any of the other cements mentioned above (Behr et al., 2003). In our study, we analyzed the impact of different dental foundations with various degrees of elasticity on the risk of veneer chipping or failure of zirconia restorations. Additionally, we investigated the marginal adaptation of these cements on abutments with various degrees of stiffness. We hypothesized that zirconia restorations require stable and stiff foundations to avoid veneer chipping or failure and to achieve sufficient marginal adaptation.

2. Material and methods

40 identically shaped one-piece polyoxymethylene (POM) and 40 identical titanium (Ti) implants were placed in polymethylenemethacrylate (PMMA) resin (Palapress Vario; Kulzer, Wehrheim, Germany). The analogs were based on the Straumann standard tissue level implant and its conventional conically formed abutment (Biomechanical Department of the University of Regensburg). This abutment measured 5.5 mm in height, had a conical angle of 6°, and was constructed for luting the dental reconstruction. Polyoxymethylene implants were used to evaluate the impact of various Young's moduli of implants on the fracture resistance of all-ceramic zirconia crowns. The implant analogs, which were copy-milled in the biomechanical laboratory of the University of Regensburg, corresponded to the well-established implant system Straumann. After scanning the identically shaped titanium and POM implants (cercon® eye, DeguDent, Hanau), individualized copings shaped in the form of a premolar were virtually designed (cercon® artv2.3, DeguDent, Hanau, D); 80 yttria-stabilized zirconia copings were milled (cercon® brain, DeguDent, Hanau, D) from white zirconia blanks (cercon® base DeguDent, Hanau, D) and enlarged by 30% to compensate for sintering shrinkage. Afterward, the copings were sintered to their final dimensions (cercon® heat, DeguDent, Hanau) at 1350 °C for 6 h. The frameworks were cleaned and degreased with alcohol (70%) and air-abraded (Sandstrahlgeraet P-G 360/3, Harnisch und Rieth, Winterbach, D) with corundum (120 μm, 2 bar). All copings were coated by hand with glass ceramic (dentine/incisal; cercon® Ceram Kiss, DeguDent, Hanau, D) as recommended by the manufacturers. To gain three-point contacts, the occlusal areas of all crowns had been adjusted to steatite beads that were used as antagonists during artificial ageing and subsequently glazed. The crowns were randomly assigned into 10 groups of 8 samples each. Five groups were cemented onto polyoxymethylene implants and five groups onto titanium implants, each with five different cements. With the exception of the automatically mixed glass ionomer cement Ketac Cem Aplicap, all luting agents were hand-mixed. Further information is listed in Table 1.

2.1. *Artificial ageing*

An artificial ageing procedure (TCML) simulated 5 years of oral service (Rosentritt et al., 1997, 2001, 2009a, 2009b, 2009c). The following loading parameters were used: 1,200,000 mechanical loads with 50 N and simultaneous thermal cycling with distilled water between 5 °C and 55 °C (3000 times for 2 min per cycle) (Gröger et al., 2003; Krejci et al., 1990; Rosentritt et al., 2001, 2009a, 2009b, 2009c). Steatite beads were used as antagonists. After ageing, the crowns were checked for failures (fracture, chipping) using a light microscope (Wild Heerbrugg, SUI), and photos were taken