DENTAL-2628; No. of Pages 10
ARTICLE IN PRESS
DENTAL MATERIALS XXX (2015) XXX.E1–XXX.E10
Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.intl.elsevierhealth.com/journals/dema

Loading capacity of zirconia implant supported hybrid ceramic crowns

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ARTICLE INFO

Article history:
Received 12 October 2014
Received in revised form
9 April 2015
Accepted 21 September 2015
Available online xxx

Keywords:
Zirconia implant
Resin composite cement
Hybrid ceramic
CAD/CAM crown
Fracture load
Compressive strength

ABSTRACT

Objective. Recently a polymer infiltrated hybrid ceramic was developed, which is characterized by a low elastic modulus and therefore may be considered as potential material for implant supported single crowns. The purpose of the study was to evaluate the loading capacity of hybrid ceramic single crowns on one-piece zirconia implants with respect to the cement type.

Methods. Fracture load tests were performed on standardized molar crowns milled from hybrid ceramic or feldspar ceramic, cemented to zirconia implants with either machined or etched intaglio surface using four different resin composite cements. Flexure strength, elastic modulus, indirect tensile strength and compressive strength of the cements were measured. Statistical analysis was performed using two-way ANOVA ($p = 0.05$).

Results. The hybrid ceramic exhibited statistically significant higher fracture load values than the feldspar ceramic. Fracture load values and compressive strength values of the respective cements were correlated. Highest fracture load values were achieved with an adhesive cement (1253 ± 148 N). Etching of the intaglio surface did not improve the fracture load.

Significance. Loading capacity of hybrid ceramic single crowns on one-piece zirconia implants is superior to that of feldspar ceramic. To achieve maximal loading capacity for permanent cementation of full-ceramic restorations on zirconia implants, self-adhesive or adhesive cements with a high compressive strength should be used.

1. Introduction

As an alternative to the well-established dental implants made from titanium, zirconium dioxide has been introduced. Zirconia is an inert, non-resorbable and biocompatible metal oxide, which facilitates osseointegration in the form of 3–5 mol% yttria stabilized polycrystalline tetragonal zirconia (Y-TZP) [1,2]. Esthetic considerations or potential allergies indicate the use of zirconium dioxide instead of titanium, and

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http://dx.doi.org/10.1016/j.dental.2015.09.012

clinical short-term success rates are promising [3–5]. However, due to the lack of long-term data the use of zirconia implants in routine clinical practice is not yet recommended [3].

Implant and suprastructure consist of different materials functioning together as a complex system in withstanding strong intraoral bite forces. Maximum biting forces are reported to be in the range of 286–847 N in the anterior and molar region, respectively [6,7]. Due to its excellent characteristics such as esthetical properties, chemical stability, biocompatibility, and a coefficient of thermal expansion similar to the natural tooth [8] ceramic might be the material of choice for implant restorations. Unfortunately, under tensile stress ceramic is susceptible to fracture as a result of its brittleness, surface and bulk defects and crack propagation under oral function [9].

In order to improve the reliability of ceramics a novel polymer infiltrated ceramic was developed [10–12]. For this material a fracture toughness of 1.21 MPa $m^{1/2}$ [12] is reported, which is higher than the one of a typical dental feldspar ceramic (0.92–1.12 MPa $m^{1/2}$) [13]. In parallel the hybrid ceramic showed a three times lower hardness value (2.92 ± 1.92 GPa) compared to the feldspar ceramic (10.64 ± 0.46 GPa) [14,15]. In a three point bending test a flexure strength of 144.44 ± 9.61 MPa was measured [12]. Due to its low modulus of elasticity of 31.72 ± 1.43 GPa [12] the hybrid material may work as a buffer area to counterbalance the stiffness of zirconia implants, which is owed to the high elastic modulus of zirconia in the range of 200 GPa [16] and the ankylotic connection to the bone as a result of osseointegration.

When investigating the performance of hybrid ceramic restorations the influence of the cement as an intermediate layer has to be considered. The impact of the cement type on fracture load values of tooth supported restorations has been analyzed in several investigations [17–19]. The use of a conventional zinc phosphate cement resulted in lower fracture load values for feldspar and resin composite crowns than a cementation with adhesive cement [18]. Glass-infiltrated alumina as well as lithium disilicate and leucite reinforced ceramic crowns luted with a resin composite cement showed higher fracture load values than those luted with a resin modified glass ionomer cement [19]. On a steel analogue of a prepared upper canine, fracture load values of zirconia, lithium disilicate or ceramic fused to metal crowns were not influenced by the type of cement [20]. This was explained by the fact that the intrinsic strength of these materials was so high that cementing with an adhesive cement could not contribute to the fracture strength. In contrast the fracture load of leucite reinforced glass-ceramic crowns significantly increased by the use of adhesive cement when being compared to glass ionomer cement [20].

The test design has a strong impact on fracture load test results. For instance feldspar ceramic as one of the weaker materials among ceramic systems has been tested with fracture load values of 300–1279 N while using different fracture load test designs [18,21,22]. Fracture load values of 833.4 ± 147.5 N [22] and 1272 ± 109 N [21], respectively were found in two different studies where machined feldspar ceramic crowns were cemented with an adhesive resin composite cement on human teeth or epoxy duplicates of a prepared tooth. These observations indicate that test results cannot easily be matched and a control group is essential in every investigation.

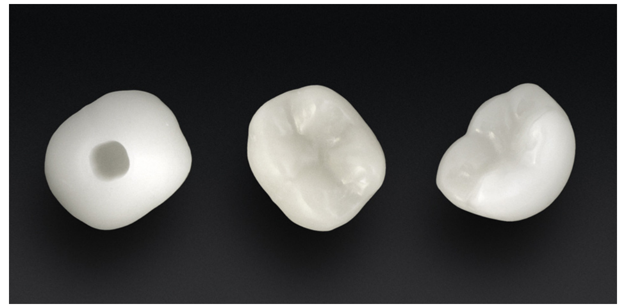

Fig. 1 – Uncemented crown specimens.

The objective of this study was to compare the fracture load values of a new hybrid ceramic material with a feldspar ceramic on zirconia implants while using different luting cements and to detect any correlation between the fracture load values of the ceramics and mechanical properties of the cements. The hypotheses are that (1) the fracture load values of hybrid ceramic crowns are higher than those of feldspar ceramic crowns and (2) fracture load values of feldspar and hybrid ceramic crowns are influenced by mechanical properties of the cement.

2. Materials and methods

2.1. *Implant preparation*

Ten one-piece zirconia implants (ceramic implant, VITA Zahnfabrik, Bad Säckingen, Germany) with a diameter of 4.0 mm, a length of 10 mm in the endosseous part and a machined abutment surface (R_a = 0.42 ± 0.06 μm) were used for this study. All implants were embedded according to ISO 14801:2008 in epoxy (RenCast CW 20/Ren HY 49, Huntsman Advanced Materials, Duxford, UK) in order to simulate the elasticity of human bone. The implants were inserted with a 3 mm clearance between implant neck and resin surface as required by the standard.

2.2. *Crown preparation and cementation*

One implant was scanned with an optical scanner (inEos Blue, Sirona, Bensheim, Germany). A standardized molar crown (46) was designed by CAD-software (inLab SW4.0, Sirona) and milled (inLab MCXL, Sirona) (Fig. 1).

Hundred crowns of a feldspar ceramic (Vitablocs Mark II, VITA) and 100 crowns of a hybrid ceramic (VITA Enamic, VITA) with polished occlusal surfaces were produced following the manufacturer's recommendations. All crowns were milled with the same design and equipment. Surface polishing was performed manually as it is common practice in a dental laboratory. Trimming and smoothing was done with white polishers, silky luster achieved with pink polishers (porcelain polishers white medium and porcelain polishers pink fine, Hager & Meisinger, Neuss, Germany). All crowns were finally polished with a goat hair buffing wheel and polishing paste (Wetzler Dental, Bielefeld, Deutschland). Prior to cementation crowns and implants were properly cleaned in an ultrasonic

Please cite this article in press as: Rohr N, et al. Loading capacity of zirconia implant supported hybrid ceramic crowns. Dent Mater (2015), http://dx.doi.org/10.1016/j.dental.2015.09.012