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Research Paper

Load-bearing capacity of soldered and subsequently veneered 4-unit zirconia FDPs

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ABSTRACT

Objectives: This study evaluated and compared the impact of soldering on fracture resistance of veneered 4-unit fixed dental prostheses (FDPs).

Materials and methods: Forty-eight 4-unit zirconia frameworks were milled and randomly divided in four groups ($n=12$). Untreated frameworks served as control, one group underwent thermal treatment, one group was sectioned and soldered in the connector between both pontics and one group was sectioned and soldered centrally in the mesial pontic. All frameworks were veneered with glass-ceramic material in powder build-up technique. The fracture load was determined on two different failure types, namely on chipping of the veneering ceramic and on total fracture of the FDP. Data were analysed using descriptive statistics, one-way ANOVA together with the Scheffé post-hoc test and Weibull statistics ($p<0.05$).

Results: The mean range of fracture load of chipped FDPs was determined between 655 N and 789 N; no differences between the tested groups were found ($p=0.587$). The mean fracture load until total fracture ranged in all tested groups from 768 N to 1261 N. Sound FDPs and soldered FDPs in the connector area presented lower mean total fracture load compared to soldered FDPs in the pontic ($p<0.001$).

Conclusions: Soldered zirconia frameworks showed similar in-vitro performance compared to sound frameworks.

1. Introduction

Zirconia based restorations exhibit high biocompatibility (Piconi and Maccauro, 1999), good aesthetics and similar mechanical properties compared to those of metal-ceramics (Filser et al., 2001). Therefore, zirconia is suitable to substitute metal-ceramic for fixed dental prostheses (FDPs). The clinical applicability of yttria-stabilized zirconia (Y-TZP) for posterior FDPs has been presented in several studies (Vult von Steyern et al., 2005; Edelhoff et al., 2008; Sax et al., 2011). Zirconia restorations can be produced from prefabricated blanks by Computer Aided Design (CAD)/Computer Aided Manufacturing (CAM) milling technique. Dependent on the type of blank used, there are two different strategies for processing zirconia. First, milling can be performed in a full-sintered stage. As no further sintering is needed the fit of these frameworks is very good (Tinschert et al., 2001; Vult von Steyern et al., 2005). However, this approach is associated with shortcomings,

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such as high wear of the milling instruments and an extended milling time because of slower feed (Tinschert et al., 2001; Vult von Steyern et al., 2005). With the aim of eliminating these technical difficulties, another technique for manufacturing zirconia was developed which allowed the frameworks to be fabricated from pre-sintered zirconia (Beuer et al., 2009b). For achieving optimal mechanical properties these pre-sintered restorations have to be sintered to full density. This post-milling heat treatment is attended by a high sintering shrinkage ranging from 15% to 30% (Reich et al., 2005; Sax et al., 2011) thus demanding the correction of the resultant changes in framework dimensions. Both the mechanical properties of the material and the specified fabrication process can considerably affect the long-term clinical performance. The fit of restorations milled from pre-sintered blocks might be inferior due to inaccuracies resulting from the sintering shrinkage, the scanning procedure, compensatory software design, and milling process. In-vitro investigations have failed to show the superiority of CAD/CAM zirconia frameworks over cast alloy frameworks regarding fit (Reich et al., 2005; Wettstein et al., 2008). Moreover, the sintering shrinkage of the pontic and distortion of the zirconia framework during post-milling sintering of 3- and 4-unit FDPs has been shown to affect marginal and internal fit (Kunii et al., 2007). Clinical studies also reported poor marginal fit for zirconia frameworks associated with biological problems (Sailer et al., 2006; Sax et al., 2011). Poorly fitting restorations may accelerate mechanical failure, due to abutment caries or screw failure in the case of implant abutments (Felton et al., 1991). Furthermore, the advent of implants in dentistry necessitated passive fit of complex restorations (Abduo et al., 2011). In tooth-supported restorations, the periodontal ligament and the cement layer can compensate inaccuracies to a certain extent. However, for FDPs on rigid implants, a higher precision is required. CAD/CAM milling of pre-sintered zirconia was reported to lead to a magnitude of distortion similar to that after casting frameworks with CoCr alloys (Abduo et al., 2011). Soldering might be the answer for trying to overcome deficient fit. It may improve dimensional precision or reduce the distortion. For metal cast alloys, soldering has been applied for many years. In soldering alloys, an intermediate alloy or solder is employed to unite the parts to be joined (Byrne, 2011). For zirconia, zirconhotbond, a silica-based ceramic solder, is available on the market for the joining of zirconia understructures in dentistry. To our best knowledge, there are no studies evaluating the influence of soldering of zirconia restorations on fracture load results. Therefore, the purpose of this study was to examine the influence of soldering on the fracture load of 4-unit FDPs. The hypothesis tested was that soldered FDPs show lower fracture load values compared to non-soldered ones.

2. Material and methods

This study tested the fracture load of zirconia FDPs soldered with zirconhotbond DD Bio ZS. The list of materials used in this study, the manufacturers and their lot numbers are presented in Table 1.

2.1. *Master model*

In order to produce standardized frameworks, a steel model with two abutments simulating an FDP between a canine and a first molar was used. Abutments of this model had flat occlusal surfaces and a ball end. They were cylindrical (height: 5 mm; diameter canine: 7 mm; molar: 8 mm) with a 1 mm circular shoulder and 6° taper and were surrounded by a 0.75 mm layer of plastic cover that allowed for simulation of the periodontium (Rosentritt et al., 2011). The holder of the test set-up was made of aluminium alloy having cylindrical holes in a distance of 23.2 mm.

2.2. *Fabrication of the zirconia frameworks*

The shape of the steel model was digitised (inEos Blue, Sirona, Bensheim, Germany) and an anatomically supported zirconia framework was designed (Cerec 3D, software version 3.10, Sirona). 48 identically-shaped 4-unit frameworks were milled from pre-sintered zirconia (DD Bio ZS blanks, Dental Direkt, Bielefeld, Germany) using a labside CAD/CAM-system (Cerec MC XL, Sirona). The connectors had a cross-sectional area of 13.7 mm^2, an occluso-gingival height of 3.5 mm, and a buccolingual width of 5.0 mm.

After milling, the zirconia frameworks were randomly divided into four groups ($N=48$, $n=12$ per group). Group 1 was left sound; group 2 was submitted to thermal treatment (Table 2). The frameworks of group 3 and 4 were separated each at one point using a diamond separating disc (Dynex Separating discs Brillant, Renfert, Hilzingen, Germany). In group 3, the frameworks were separated perpendicularly at the mesial pontic, in group 4 in the connector area between the first premolar and the second premolar. The gap width amounted to 0.7 to 1.0 mm. In order to achieve neat cutting surfaces, they were reworked with a water-cooled air-turbine (KaVo, EXPERTtorque E680 L, Biberach/Ri, Germany). Subsequently, the enlarged frameworks were sintered to full density according to the manufacturer's instructions (Vita ZYromat, Vita Zahnfabrik, Bad Säckingen). The surfaces to be joined were air-abraded (CEMAT NT4, Wassermann Hamburg, Germany) using alumina powder (10 s, 2 bar, distance: 10 mm) with a mean particle size of 50 μm (Renfert, Hilzingen, Germany). Then, the separated frameworks were soldered with a ceramic solder (zirconhotbond, DCM GmbH, Rostock, Germany). A silicone key (dentona 1:1 gum, Dentona AG, Dortmund, Germany) was made by using of a sound FDP to achieve standardized fixation of the separated frameworks on the plaster model. The zirconia surfaces to be soldered were evenly covered with the zirconhotbond (DCM GmbH) material. The two parts of the framework were assembled on the plaster model, the fit was verified by means of the silicon key, and additional solder material was applied. Subsequently, the solder material was solidified by applying heat from a high power hair dryer. In order to avoid any movement of the segments during the sintering process, liquid firing cotton (zirconhotbond fix, DCM GmbH) was used to create a custom firing tray. The FDP was placed on a regular firing tray (Vita Zahnfabrik, Bad Säckingen, Germany) and the solder was sintered according to the manufacturer's instructions (Vita Vacumat 40 T, Vita Zahnfabrik). After cooling to