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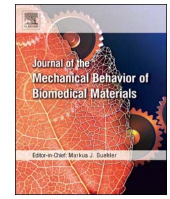

Custom Morse taper zirconia abutments: Influence on marginal fit and torque loss before and after thermomechanical cycling

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ABSTRACT

The use of zirconia abutments has increased because of aesthetics, but sometimes customization is necessary and its effect is unclear. This study evaluated the marginal fit and torque loss of customized and non-customized aesthetic zirconia abutments associated with Morse taper implants before and after thermomechanical cycling. Twenty-four implant/abutment/crown sets were divided into three groups (N = 8): Zr - non-customized zirconia abutments, Zrc - customized zirconia abutments, and Ti - titanium abutments. The ceramic crowns of the upper canines were made. All of the abutments were tightened with 15-N.cm torque, and the crowns were cemented on the abutments. The misfits and torque loss were measured before and after thermomechanical cycling. The marginal fit was evaluated in two planes throughout 10 different slices, 30 measurements for each face (i.e., buccal, palatal, mesial and distal) and 120 measurements for each sample. A load of 100 N, a frequency of 2 Hz and 1000,000 cycles with temperature variation of $5\,^{\circ}-55\,^{\circ}\mathrm{C}$ were used for thermomechanical cycling. Thermomechanical cycling significantly decreased the marginal misfit only with the Zrc ($p = 0.002$), and the Ti was significantly different from the Zr and Zrc before and after thermomechanical cycling. Thermomechanical cycling did not affect the torque losses of the groups, but a significant difference between the Zr and Zrc ($p = 0.0345$) before cycling was noted. Customization of zirconia abutments does not significantly affect torque loss and marginal misfit after thermomechanical cycling suggesting that they can be safe for clinical utilization.

1. Introduction

Ceramic abutments on implant-supported prostheses have been increasingly used because at areas with thin gingival tissue (Garine et al., 2007), these abutments allow light transmission through peri-implant tissues (Boudrias et al., 2001; Vigolo et al., 2006), and provide aesthetics similar to those of natural teeth (Boudrias et al., 2001; Yildrim et al., 2003), which is a feature desired by patients and professionals.

Prefabricated zirconia abutments for Morse taper connections aim to combine the aesthetics of zirconia and the mechanical and biological advantages of Morse taper connections. Such connections provide better fits between the implant and abutment, decrease the passage of bacteria passage through the gap, and prevent the consequent peri-implant bone resorption (Bozkaya and Müftü, 2003, 2005; Khraisat et al., 2002; Perriard et al., 2002; Norton, 1999). Additionally, mechanical stability is improved, and abutment loosening is avoided because the retention of the Morse taper connection is more attributable to the frictional retention of the conical walls than to the screw threads (Bozkaya and Müftü, 2005; Khraisat et al., 2002; Perriard et al., 2002; Norton, 1999; Weigl, 2004).

A marginal fit is required for successful implant-supported rehabilitation to avoid bacterial leakage, biofilm accumulation, cement dissolution, and periodontal diseases. Therefore, studies have tried to establish a limiting value for crown marginal misfit. Many authors consider marginal misfits between 100 and 150 μm to be clinically acceptable (Jemt, 1991; Beuer et al., 2009; Koç et al., 2016; Lopez-Suarez et al., 2016; Pasali et al., 2017). Different methods have been used to evaluate crown/abutment marginal misfits, e.g., visual clinical inspection with a mirror and periapical radiography, optical microscopy, and computerized microtomography. The latter is a non-destructive method that evaluates the marginal fit and internal space in two (2D) and three (3D) dimensions at a micrometrical scale and at different positions and directions (Demir et al., 2014; Silveira et al., 2017).

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Research evaluating the biomechanical behavior of implants associated with aesthetic prosthetic abutments has increased, but several of these studies have evaluated hexagonal abutments. Thus, questions about the behavior of zirconia abutments remain, especially those that require customization for clinical use. Studies have suggested that customization by wear or other surface mechanical treatments can affect the structure of the zirconia and elicit residual stresses that can influence mechanical properties of these abutments (Sundh et al., 2005). Thus, the aim of this study was to evaluate mechanical behaviors of customized and non-customized aesthetic zirconia abutments in association with Morse taper implants through marginal fit analysis and torque loss before and after thermomechanical cycling. The null hypothesis of this study was that neither thermomechanical cycling, abutment material or the customization of the abutments would influence the marginal misfit or torque loss.

2. Materials and methods

For this study, 24 Morse taper titanium implants of 4.5 × 11 mm (Ankylos Plus, Dentsply Friadent, Sao Paulo, Brazil) were embedded in polyurethane (F16, Axson, Cergy, France) with elastic properties and elastic moduli similar to those of human lamellar bone tissue (polyurethane: 3.6 GPa and lamellar bone: 4.0–4.5 GPa) (Wiscott and Belser, 1999). The implants were placed at a 30-degree angulation (ISO 14801), and their platforms were 3 mm above the polyurethane surface to simulate a 3-mm bone resorption (Khraisat et al., 2002).

According to the abutment used, the implant/abutment sets were divided into three groups (N = 8) as follows:

Group Zr: zirconia abutments (Zirconia Anterior Cercon Balance, Dentsply, Friadent) measuring 5.5 mm in diameter, 6.5 mm in height and 3.0 mm in gingival height.

Group Zrc: zirconia abutments (Zirconia Anterior Cercon Balance, Dentsply, Friadent) measuring 7.0 mm in diameter, 7.5 mm in height and 3.0 mm in gingival height, that were customized.

Group Ti: titanium abutments (Anterior Cercon Balance, Dentsply, Friadent) measuring 5.5 mm in diameter, 6.5 mm in height and 3.0 mm in gingival height (control group).

2.1. Zirconia abutment customization

The abutments of the Zrc group were prepared with the aid of an equipment that standardized wear of the axial and incisal walls with vertical and horizontal rods of the millimetric scale without irrigation. The wear was applied with a coarse-grained diamond polisher drill (DYP-13g, EVE Diasynt-Plus, Pforzheim, Germany) at low speed according to the manufacturer's recommendations. The abutments were worn at 1.0 mm at the incisal and 0.75 mm at the axial faces to achieve the same dimensions of the abutments of the Zr group. Polishing was performed with medium coarse-grained drills (DYP-13m EVE Diasynt-Plus, Pforzheim, Germany). One set of drills (coarse-grained and medium coarse-grained) was used to prepare each abutment. Next, the abutments were evaluated on a profile projector to determine whether the dimensions of the customized abutments were similar to those of the non-customized abutments.

After customization, one customized and one non-customized zirconia abutment were evaluated via scanning electronic microscopy (SEM) to compare the surfaces.

The abutments were installed on the implants with 15-N.cm torque (initial torque) according to the manufacturer's instructions measured with a digital torquemeter (TQ 680, Instrutherm Instrumentos de Medição Ltda., Sao Paulo, Brazil). After 10 min, the torque removal (i.e., preload removal torque) was measured to evaluate the settling effect. The torque was reapplied and confirmed 10 min later (i.e., confirmation torque) for thermomechanical cycling (Moris et al., 2015).

2.2. Crown construction

To simulate the oral environment, a load was applied to the crowns instead of the abutments as in a previous study (Andreiotelli and Kohal, 2009). Next, 24 upper canine crowns were made. For this, all of the abutments were scanned, and copings were created with computer-aided design and computer-aided machining (CAD/CAM, LAVA, 3 M ESPE, Brazil). After the construction of the copings, the aesthetic veneers were waxed, and a condensation silicone (Zetalabor, Badia Polesine) matrix was used to standardize the aesthetic veneer waxing. Next, the aesthetic veneering ceramic (IPS E.max Zirpress HT A2, Ivoclar Vivadent, Schaan, Liechtenstein) was heat-pressed on zirconia copings.

The crowns were cemented on the abutments with the provisional cement Rely X Temp NE (3M ESPE AG, Seefeld - Germany) under a load of 5 N for 10 min with the aid of a dental surveyor. After the cement cured, the excess was removed.

2.3. Marginal fit

Before the thermomechanical cycling, all sets (implant/abutment/crown) were scanned in micro-CT (Skyscan 1176, Kontich, Belgium). The parameters used were 90 kV, 278 mA with 18 μm resolution, 360° rotation and 1 step. The filter used was 0.1 mm Cu. The reconstructions were performed with NRecon software (SkyScan, Kontich, Belgium) with the following image adjustments: smoothing = 4, ring artifact correction = 20, and beam hardening correction (%) = 38. These parameters were used to eliminate artifacts and obtain ideal pictures for measuring the misfits.

Subsequently, the images were transferred to Data Viewer (SkyScan, Kontich, Belgium) and reproduced in sagittal and coronal planes to analyze the possible failures and to evaluate the marginal fits using the linear measurement tool that is available in the CTAn software (Skyscan, Kontich, Belgium). The marginal fits were evaluated in the sagittal (mesial and distal faces) and coronal (buccal and palatal faces) planes throughout 10 different slices spaced at a distance of 0.4 mm (Fig. 1), and 3 measurements were made on each slice, which resulted in 30 measurements for each face (i.e., buccal, palatal, mesial and distal) and 120 measurements for each sample.

2.4. Thermomechanical cycling

Thermomechanical cycling was performed in an electromechanical fatigue test machine (BIOPDI, Sao Carlos, Sao Paulo, Brazil). A load of 100 N (Paphangkorakit and Osborn, 1997) was applied to the palatal surfaces of the crown at 30 degrees of angulation in relation to the long axis of the implants (ISO 14801) (Sailer et al., 2009) at a frequency of 2 Hz and for 1000,000 cycles. During the test, the samples were immersed in distilled water and subjected to approximately 8400 thermal cycles with temperature variation of 5–55 °C (Fig. 2).

After thermomechanical cycling, the sets were removed from the equipment and scanned again to evaluate the marginal fits as described above. Next, the crowns were decemented by submitting the sets to uniaxial tensile strength in a universal testing machine (EMIC MEM 2000, Sao Jose dos Pinhais, Parana, Brazil) at a speed of 1 mm/min.

After crown decementation, the abutment removal torque was evaluated (postload removal torque) to calculate the percentages of torque loss before and after the thermomechanical cycling according to previous methodology (Moris et al., 2015).

The data were described as central positions and dispersion measures. To evaluate the effects of groups and time on the misfit, the generalized estimation equation (GEE) method was used (McCullagh and Nelder, 1989) to estimate the parameters of a generalized linear model with a gamma distribution and a function of identity linking. Structures for the correlated data were considered when there were measures throughout the time for the same sample (Zeger and Liang,