EFFECT OF CYCLIC LOADING ON ZIRCONIUM ABUTMENT SCREW LOOSENING

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INTRODUCTION

Although metal implant abutments have esthetic inherent disadvantages, they are most widely considered a standard treatment option for implant supported restorations. Improved material characteristics, compliance with clinician’s and patient’s increased demands for highly esthetic results, have contributed significantly to the development of a new generation of ceramic abutments. Yttrium-oxide stabilized zirconium dioxide (Y-TZP) has been noted for its both-like color, high load strength, tissue tolerability and intra-sulcular design enhancement. The prevention of transformation toughening of zirconium-dioxide results in extremely high component strength, extraordinary bonding and biaxial strength, fracture and chemical resistance. To be considered a true alternative, the mechanical and biological qualities of ceramic implant abutments have to be superior to those of widely used titanium abutments. These requirements can only be met by high-performance and biocompatible oxide ceramics. Oxide ceramics are equal to metals from a mechanical standpoint, but biologically stronger. However, one exception is the high brilliance of ceramics, and the risk for crack propagation. So far, the use of full ceramic implant abutments for implant restorations has been limited due to this feature. Abutment and prosthetic loosening of single and multiple screw-retained, implant-supported fixed partial crowns is a concern in general. The purpose of this study was to determine the fracture strength of zirconium-dioxide implant abutments and the torque required to unload the retainer screw prior to and after applying cyclic loading to the implant-abutment assembly. In addition, the dynamic behavior and stress distribution pattern of zirconium abutments, using the transient dynamic analysis of Finite Element Modeling (FEM), was evaluated.

MATERIAL AND METHODS

A laboratory study according to the International Standards (DIN ISO/ WD 14901 Rev (F), International Organization for Standardization) was carried out, simulating the functional loading of an endosseous dental implant body and its abutment components under worst case conditions. Straight CERCON® zirconium-dioxide implant abutments were assembled to seven internally hexed XIVE™ implants, 4.5 mm in diameter and 18 mm in length (DENTSPLY Friadent, Mannheim, Germany). All implants were embedded into an elastic material (Epofil, Stuers, Ballaupen, Germany) with a Young’s modulus of 4100 MPa, being similar to that of bone. The top of the implant extended three millimeters above the level of the surrounding material in order to create a worst-case situation of crestal bone resorption. Spherical caps were fabricated and cemented (Tampax, Kent, California, USA) on each zirconium-dioxide implant-abutment and adjusted to the same 8 mm length in order to create defined lever forces. During loading, the spherical cap rested on a flat plate. The load was applied via a stainless steel rod (plasted and using a small eccentric point) to withstand external forces and to avoid undefined lateral forces in the set-up. Cylindrical loading tests (CLTS) were carried out to define a linear hydraulic dynamic testing machine (Instron 8872, Canton, VA, USA) at loads between 150 and 1050 Newton up to five million loading cycles, at 15 Hz. The tests were performed by applying a compression load 30° off the axis of the implant. This resulted in a combination of compression, bending, and shear loads in the device. The tests were performed both statically for single overload conditions, and in repeated loading to provide fatigue curves of load versus cycles required to cause failure. The same implant type (XIVE™) was used for both the static load test (0.05 inch/ minute crossed speed) and the fatigue tests (15 Hz). The torque values required to unfasten the retaining screws were determined with a Torinchi torque gauge (Torinchi America Corporation, Northbrook, IL, USA). In addition, the dynamic behavior of the zirconium-dioxide implant abutments was analyzed by transient dynamic analysis of the Finite Element Modeling (FEM); a software optimization method based on a Computer-Aided Design (CAD) of prosthesis. A mathematical mesh was superimposed to the drawings of the components and the virtual load was chosen according to clinical conditions in the oral cavity. An identical set-up was selected for the computer analysis with straight abutments. External loads of 150 and 250 Newton were applied to the assembly at a 30° inclination towards the axis of the implant. FEM was carried out by ProMechS TANAGA software (Paradigm Technology Corporation, N Chelsea, MA, USA) -damping van der-Mises and maximum stress levels obtained from the calculations.

RESULTS

The CERCON® zirconium-dioxide ceramic abutments investigated in this current study fulfilled a maximum fracture strength of 632 N during static loading, and during cyclic loading 26 N at 800,000 to 5,000,000 cycles run out point, and respectively, 433 N at 10,000 cycles run-out point. The mean torque required to unfasten the abutment retaining screws after (crusial) tightening was 21 Nm ± 1 nm respectively 23 Nm ± 1 (measurement accuracy ± 2 Nm) after loading up to five million cycles i.e. screw loosening did not occur. Within the limit number of test specimens (7), the difference was statistically not significant. The FEM analysis revealed a pattern of low, well-distributed stresses along the entire implant-abutment assembly at an external load of 100 N. However, higher stress peaks up to 400 MPa have been shown at the cervical aspect of the zirconium-dioxide abutment and at the apical third of its retaining screw at an external load of 250 N.

CONCLUSION

Restorations in the esthetically demanding anterior region present significant challenges in both the surgical and prosthetic stages of implant dentistry. Titanium has been established as the material of choice for endosseous implants, resulting in a high degree of predictability. Zirconium-dioxide ceramics appears to be a suitable material for implant restorations. Within the limitations of this study zirconium-dioxide implant abutments exceeded the established values up to 300 N for maximum initial force reported in the literature and tightly fits into the titanium implant after several millions of loading cycles. Compared to titanium abutments, it shows a low bacterial colonization potential and minimizes the gray color associated with metal components shining through zirconium abutments. This durability and color conformity are prerequisites for highly esthetic implant restorations.

Literature


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