INTRODUCTION
Although metal implant abutments have aesthetic inherent disadvantages, they are most widely considered a standard treatment option for implant-supported restorations. Improved material characteristics, compounding with clinician’s and patient’s increased demands for highly aesthetic 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-ocular design enhancement. The prevention of transformation toughening of zirconium-dioxide results in extremely high component strength, extraordinary bending and brittle strength and fracture and chemical resistance. To be considered a true alternative, the mechanical and biological qualities of ceramic implant abutments need to bearser than those of widely used titanium abutments. These requirements can only be met by high-performance and incompatible oxide ceramics. Oxide ceramics are equal to metals from a mechanical standpoint, but biologically stronger. However, one exception is the high brilliancy of ceramics, and the risk for crack propagation. So far, the use of common ceramic implant abutments for implant restorations has been limited due to the feature: Abutment and prosthetic loosening of single and multiple screw-retained, implant-supported fixed partial dentures 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 unseat the retaining 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 14801 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. Strictly CERCON® zirconium-dioxide implant abutments were assembled to seven internally hexed XIVE™ implants, 4.5 mm in diameter and 18 mm in length (DENSTIPLY Friadent, Mannheim, Germany). All implants were embodied into an elastic material (ElpoFlex, Rüters, Ballenup, 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 (TempBlock™, 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 (pol-socketed using a small center drill point) to withstand external forces and to avoid unintended lateral forces in the setup. Cyclic loading tests (CLT) were carried out by means of a servo hydraulic dynamic loading machine (Instron 8872, Canton, Canton, MA, USA) at loads between 100 and 545 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 simple 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 tests (0.05 inch/minute crossed speed) and the fatigue tests (15 Hz). The torque values required to unseat the retaining screws were determined with a Torsichs force gauge (Torsichs America Corporation, Northbrook, Ill., 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 the implant-abutment assembly. A mathematical mesh was superseded to the drawings of the implant and abutment assembly. Subsequently, a virtual load was chosen according to clinical conditions in the oral cavity. An identical set-up was selected for the computer analysis with strain abutments. External loads of 100 and 250 Newton were applied to the assembly at a 30° inclination towards the axis of the implant. FEM was carried out by ProMach TM/MAXIAA software (Parametric Technology Corporation, Needham, MA, USA) and varying strain and maximum stress levels obtained from the calculation.

RESULTS
The CERCON® zirconium-dioxide-ceramic abutments investigated in this current study satisfied a maximum fracture strength of 672 N during static loading, and during cyclic loading 280 N at 800,000 to 5,000,000 cycles (breakout-point, respectively). 403 N at 10,000 cycles (n=1, p=0.000,000), respectively. The mean-torque value required to unseat the abutment retaining screws after (n=1) tightening was 21 Ncm ± 1 respectively. A 2 Ncm ± 1 measurement accuracy ± 2 Ncm after loading with up to five million cycles i.e. screw loosening did not occur. Within the limits of this study, the zirconium-dioxide implant abutments exceeded the established values of up to 300 N for maximum initial force reported in the literature and tightly fit into the titanium implant after several million of loading cycles. CERCON® zirconium-dioxide ceramics show a low bacterial colonization potential and minimize the gray color associated with metal components shining through the dental tissues. Their durability and color conformity are prerequisites for highly aesthetic implant restorations.

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 many applications. Within the limitations of this study, zirconium-dioxide implant abutments exceeded the established values of up to 300 N for maximum initial force reported in the literature and tightly fit into the titanium implant after several million of loading cycles. CERCON® zirconium-dioxide ceramics show a low bacterial colonization potential and minimize the gray color associated with metal components shining through the dental tissues. Their durability and color conformity are prerequisites for highly aesthetic implant restorations. 

Literature