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Fractographic analyses of failed one-piece zirconia implant restorations

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ABSTRACT

Background. Promising results of initial clinical trials with yttria-stabilized zirconia have led to more extensive use of zirconia in dental implant superstructures. The applications have extended to abutments and complex individually designed crown-abutment one-piece structures. Little is known about their clinical success and the primary cause of failures.
Purpose. The aim of this study was to identify the cause of fracture of retrieved implant-retained one-piece prostheses that failed during clinical use.
Methods. Nine fractured restorations were analyzed with fractographic methods and their fracture origins were identified.
Results. All but two of the fractures originated in an area of tight contact between the implant or titanium screw and the abutment base. Results of the evaluation showed that zirconia-based implant restorations with very thin walls in the region connecting the prosthesis to the implant are vulnerable to damage from the screw retaining process and fracture from non-axial loads. Two restorations failed due to veneer fractures.
Significance. The findings suggest that large crowns on narrow implants or implants with internal fixation should preferably not be made with zirconia abutments, or that a new design approach should be considered.

1. Introduction

Yttria-stabilized tetragonal polycrystalline zirconia (Y-TZP) offers an alternative to metal as a core material for implant-retained prostheses. In fact, it is increasing in popularity, largely due to the favorable esthetic appearance. However, clinical trials report a somewhat higher incidence of porcelain veneer and abutment fractures in Y-TZP when compared to metal-based restorations, and the survival rates appear lower than for metal-ceramic counterparts [1–5].

Promising results of initial clinical trials with dental zirconia have led to more extensive use of zirconia in implant superstructures. That success has facilitated extension to abutments and complex individually designed crown-abutment structures, also called “one-piece” restorations [6,7]. Yet, there is limited scientific clinical evidence of this treatment modality. Based on oral communications

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with practicing dentists, as well as very recent reports, it seems that fractures occur relatively frequently, and include both veneer and core fractures [8–12]. For instance, one study reported an increased fracture rate for a specific type of zirconia abutments with internal fixation [13]. The design and development of titanium inserts for use in zirconia-based abutments is aimed at reducing the stress during insertion, which suggests that the manufacturers are concerned about fractures as well. Unfortunately, there have been no quantitative reports concerning the number of Y-TZP restorations that need replacement, as has been increasingly common for orthopedic implants [14,15]. Not only is there limited knowledge concerning the amount of revisions required, but also the primary reasons for the revisions performed on dental implant-retained Y-TZP restorations are not clear.

In general, the implant manufacturers have a refund policy requiring the dentist or dental technician to return the broken part in order to receive a new restoration free of charge. This is, of course, beneficial for the economy of the patients, but each revision takes time, effort and increases the risk of complication. Fractures of ceramic dental prostheses release small sharp objects into the oral cavity, which can potentially cause cuts in the oral mucosa. There is also danger of swallowing the small pieces or even inhalation, both with potentially serious risks. Furthermore, the return policy complicates objective retrieval analyses.

Clinical trials are expensive and time-consuming. Usually, a low number of carefully selected participants are included. The dentists have sufficient time to do their work and the patients are often positively inclined toward both treatment and practitioners. Patients with malfunctions, excessive wear and severe diseases are normally excluded. Skeptical and negative patients decline to be included. Consequently, the results from clinical trials are not fully representative of everyday clinical practices where all types of patients need treatment and the dentist is usually always pressed for time. Clinical trials are nevertheless important for assessing how different treatment modalities can function under optimal circumstances. Nevertheless, the results must be compared to everyday clinical practice and followed up by retrieval analyses of failed cases in order to get the full picture of potential problems regarding a certain treatment.

In order to reduce the risk of fractures in future components, it is essential to find the root cause of clinical fractures. So far, this has only been performed to a very limited extent on dental implant-based restorations [16,17]. Similar studies of tooth-retained restorations have revealed important information regarding what causes the different types of restorations to fail, and new methods for clinically relevant testing of all-ceramic crowns [18–23]. This could be performed on all-ceramic implant retained restorations as well. Therefore, the aim of this study was to identify the cause of fracture of implant-retained zirconia-based prostheses that failed during clinical use.

2. Materials and methods

Nine fractured implant-based restorations were retrieved by different dentists in Norway after a period of clinical use (Table 1). These were collected by the authors and analyzed with fractographic methods in order to identify the fracture origin, the characteristics associated with crack propagation and the most probable cause of fracture. The retrieved restorations were custom-made zirconia core-veneer restorations, with integrated abutments. The restoration were thus made from one piece of zirconia from the level of the implant to the occlusal surface, but covered with a weak feldspathic veneering ceramic in visible areas. Six single crowns were made for internal connector design. One single crown and the two 3-unit restorations were made for external connector design. One crown had a slender titanium base adhesively cemented between the abutment and implant.

Prior to a cleaning procedure, the restorations were photographed in a light microscope in order to see which parts of the fractures have been exposed to the oral cavity. None of the specimens were returned with all pieces; only the major part of the restorations had been retrieved. After this inspection, the specimens were thoroughly cleaned in an ultrasonic bath in Dakins solution (NaOCl 16%) for 15 min to dissolve calculus, and then washed with 100% acetone and subsequently 98% ethanol. After completely dry, the specimens were sputter-coated with gold and inspected by Scanning Electron Microscopy (SEM) using a commercial instrument (JEOL JSM-6010Plus/LA, JEOL, Peabody, MA, US). Fractographic maps, where all fracture features indicating the direction of crack propagation are registered, were constructed for each restoration and the primary fracture origin was located following the methods described in NIST recommended practice guide [24] and in a recent ADM-guidance report [25]. Based on the analysis performed, the direction of crack propagation was determined, the origin was identified where possible, and the cause of fracture was distinguished.

3. Results

Several different fracture modes were observed and are summarized in Fig. 1. The fractures were complex and usually with multiple fracture origins. All but two of the restorations underwent core fractures at the base of the restoration, in the region that was in contact with the metal implants and screws (Figs. 2–4

). Four of the six core fractures originated from the inner wall of the cylinder, and initiated from small semicircular cracks. Cracks were identified as the critical flaw causing catastrophic failure in all these core failures. One core fracture originated from a crack in the exterior of the cylinder, and the last fracture origin was at the bottom of the abutment cylinder in the area of interlocking pattern that is intended to increase the fixation of the restoration to the implant.

Two restorations had veneer fractures only (Fig. 5A and B). One crown and one three-unit posterior restorations failed due to veneer fractures (chipping) that started from the region of screw hole on the occlusal or palatal surface. The fracture surfaces had been severely worn or damaged prior to removal and the fracture origins could not be detected. Nevertheless, it was obvious that the core was designed with insufficient cusp support, leaving large areas of weak veneering porcelain unsupported.

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