Fracture of Zirconia Abutment with Metallic Insertion on Anterior Single Titanium Implant with Internal Hexagon: Retrieval Analysis of a Failure

Keywords

Dental Implants
Zirconia
Prosthesis Failure Analyses
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Dental Porcelain

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ABSTRACT

This case report presents a retrieval analysis of a screw-retained one-piece restoration with the veneering ceramic fired directly onto the zirconia abutment that fractured during insertion. A patient who experienced root fracture of a maxillary left central incisor received a titanium implant on the same day as extraction. After delayed implant loading, a two-piece zirconia abutment with metallic insertion was customized. Upon installation, a horizontal fracture of the crown just above the metallic portion was detected. The retrieval analysis of a fractured zirconia abutment showed crack formation and diffusion of glaze material that expanded the crack line during firing.

INTRODUCTION

Patients expect success when replacing a lost dental element in the anterior region, and this requires careful planning. Currently, there are several treatment options for the restoration of missing anterior teeth, and clinicians should choose a predictable treatment based on scientific evidence. The use of implants for tooth restorations was first reported three decades ago as a treatment option for partially or fully edentulous patients.[1] Since then, metal alloys, mainly titanium, have been accepted as reliable, biocompatible substructures for implant-supported crowns. However, their gray appearance may compromise aesthetics, especially after bone resorption. Furthermore, peri-implant soft-tissue recession may lead to exposure of the metallic abutment. For this reason, abutments of aluminum oxide or zirconium are often selected to circumvent this issue,[2] since they are more aesthetic and fulfill biocompatibility requirements.[2,3]

Alumina and zirconia abutments have high fracture resistance and allow light to pass through, thus improving aesthetics.[4-8] Most implant manufacturers today offer zirconia abutments for implant-supported metal-free restorations, to meet the demand for aesthetics. Such abutments are currently available in prefabricated or custom forms and may be prepared either by the dental technician through drilling or by computer-aided-design/computer-aided-manufacturing (CAD/CAM) systems via milling techniques.[3]

In prospective studies, titanium and zirconia abutments exhibited similar survival rates from three to five years, with no statistically or clinically relevant differences for the incidence of technical, biological, and aesthetic complications.[9,10] In a study with a longer follow-up period of up to 11 years, the cumulative success rate for abutments was reported to be 96.3%.[11] In that study, two screws were lost and no biological complications were reported. Moreover, customized zirconia abutments on single implants exhibited excellent long-term outcomes in anterior and premolar regions.[11] However, fracture of zirconia abutments, although not common, has also been reported in the literature. In a systematic review of clinical outcomes of single-implant abutments in the anterior region, discrete incidence of fractures was reported, where alumina abutments fractured more often, followed by zirconia abutments.[1] To date, there have been no reported fractures of titanium and cast metal alloy abutments for the anterior region.

The unexpected failure of zirconia abutments may be related to defects in the manufacturing process, cracks in the green structure, sintering-related pre-stresses, improper handling of the material, and excessive reduction of the axial walls.[12] Also, tightening the fixation screw beyond the recommended torque could not only lead to the generation of very high stresses in this region, but also induce high stresses at the screw head, generating wedging forces inside the abutment.

In *in vivo*[13] and *in vitro*[14] fatigue studies, unmodified zirconia abutments failed in the cervical portion of the abutment, in the region adjacent to the screw and the implant platform. Thus, the implant-abutment interface design plays an important role in failure. Abutments with an inner hexagon showed better force distribution along the interface compared with those having the external hexagon.[15,16] In another *in vitro* study, internally connected abutments with a secondary metallic component exhibited the highest bending moments, whereas internally connected one-piece zirconia abutments were the weakest of those investigated.[17] Alqahtani and Flinton[18] examined the effects of different levels of preparation of zirconia implant abutments on the fracture load and observed that the preparation of prefabricated zirconia abutments negatively influenced load-to-fracture values.

In a 5-year-retrospective study, 130 patients received 185 single restorations on zirconia abutments. Low rates of technical and biological complications and a high rate of patient satisfaction were reported.[19] In that study, crown fractures were not observed, but two abutments showed early failures, one upon installation and another after 2 months of use.

Although early fracture of zirconia abutments is rare, investigations contribute to our understanding of the causes of failure, since the abutment fracture may require a new crown fabrication, generating additional costs for both the patient and the dentist. Design deficiency, material deficiency (fabrication process) or in situ stress-induced conditions can result in a failure event. Failure analysis includes examination of a fractured component in order to investigate the circumstances surrounding a failure event with the expectation of elucidating the cause of such event. According to Scherrer, Quinn and Quinn (2008),[20] the binocular stereomicroscope and the scanning electron microscope (SEM) are the main tools for performing fracture analysis. The former helps the fractographer understand the spatial relationships of the observed fracture features and the latter allows close-up of specific regions. In general, using the stereomicroscope is enough for fracture examination.

Reports of failure of zirconia abutments are scarce in the literature. This case report describes the fractographic and elemental analyses of a screw-retained restoration with the veneering ceramic fired directly onto the zirconia abutment, which fractured during insertion. The aim was to understand the reasons for failure.

CLINICAL CASE REPORT

A 53-year-old male patient received a metallic intraradicular post and single metal-ceramic crown on his maxillary left central incisor. The root fracture of this same tooth was detected eight years later during the periodic recall. After clinical and radiographic examination, followed by diagnostic plaster model evaluation, an implant-supported crown was indicated for replacement of the missing tooth. One titanium implant with an internal hexagon of 4.3 diameter (NobelReplace™) was placed on the same day of tooth extraction. Delayed implant loading was planned, so that the implant was not subjected to immediate loading. The missing tooth was temporarily replaced with an acrylic prefabricated tooth affixed to the adjacent teeth with photo-polymerized resin composite and fiber-reinforced composite.

A provisional screw-retained acrylic crown was installed after eight months of healing, and its shape was subsequently amended with acrylic added gradually to provide adequate support to the peri-implant soft tissues. The emergence profile obtained was duplicated with an impression silicone. A zirconia abutment (2-piece connection for Replace implants) with a metallic insertion (NobelProcera™) was customized, and adequate thickness of the axial walls was maintained. The implant position did not require angle correction for insertion of the abutment, which allowed for direct screwing of the crown. The abutment fit was tested in the mouth and confirmed by radiographic examination. Thereafter, a transfer mold was prepared, and the abutment was sent to the dental laboratory for ceramic veneering (Vita VM9).

The crown was tested in the mouth before final glazing, and the required occlusal and aesthetic adjustments were made. The dental technician then glazed the crown (Vita Akzent). The abutment and crown were photographed on each clinical visit as displayed in Figure 1a-f. Upon installation of the final restoration under a controlled torque of 35 Ncm, a horizontal fracture of the crown was detected just above the metallic insert area. The temporary crown was repositioned, and a new abutment was made.

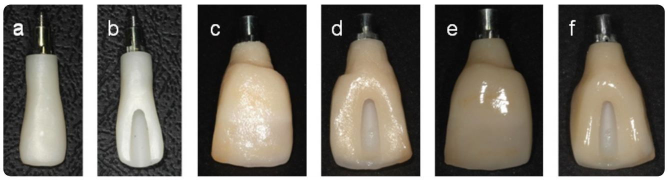

Figure 1a-f: a) buccal and (b) lingual views of the zirconia abutment; (c) buccal and (d) lingual views of the crown (21) crown before final firing; and (e) buccal and (f) lingual views of the crown (21) after glazing.

DATA COLLECTION

The patient authorized the use of the records and images of his treatment and also signed an Informed Consent. All data regarding surgical and prosthetic steps were retrieved and analyzed.

FRACTOGRAPHIC ANALYSIS

The fractographic analysis was performed according to Quinn (2007)[21] and as well as according to ASTM C1322-15 (ASTM 2015).[22] The fragments were cleaned in an ultrasonic bath (with isopropyl alcohol for 10 minutes), then dried. The coronal and cervical portions of the fractured crown were photographed with a digital camera and initially evaluated by stereomicroscopy (Zeiss Discovery V20). Then, the fracture surfaces were stained with a waterproof felt-tipped pen and green water-based ink (Paper Mate®) and examined by two experienced investigators (RM and LA).

ENERGY DISPERSIVE SPECTROSCOPY (EDS) AND SCANNING ELECTRON MICROSCOPY (SEM)

In sequence, the fractured regions (cervical and coronal portions) were cleaned again, and were mapped by EDS (Quantax EDS for SEM). They were then gold sputter-coated (Emitech SC7620) and subjected to SEM at high vacuum (INSPECT S50) operating at 15 kV, spot 5.0, and working distance of 17 mm, at magnifications ranging from 45 to 300 x.

FRACTOGRAPHIC ANALYSIS

During the stereomicroscopic inspection, some areas of the abutment appeared shiny *(Figure 2a-f)*.

The appearance of both fracture surfaces was that of a glassy material invading the abutment zone. The glossy aspect of such material suggested that it could be porcelain that had infiltrated the abutment zone in previously existing defects or defects created after adjustments and torque of the coping during proof.

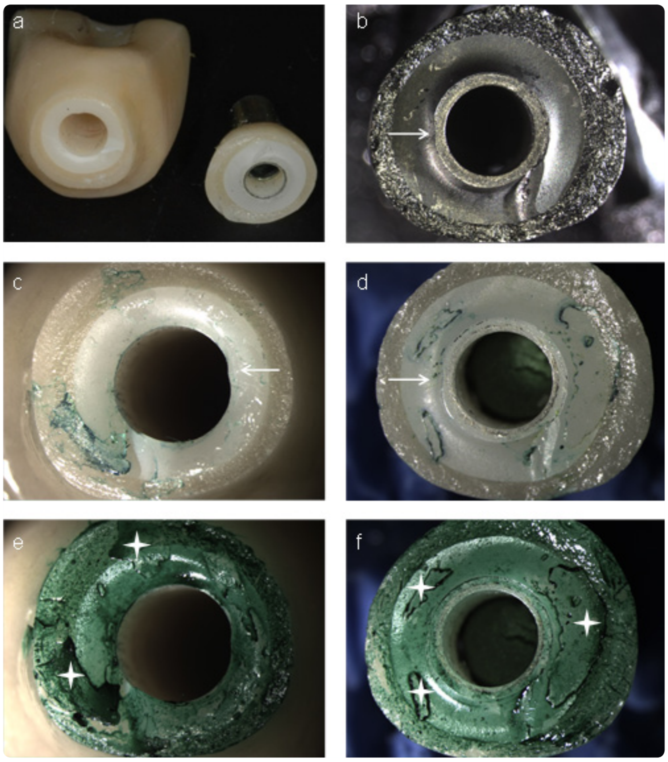

Figure 2a-f: (a) Crown fracture that occurred immediately after installation. Optical images (15 x) of the fractured crown: coronal (b, d, f) and cervical (c, e) fragments, showing a constriction (arrows) in the inner edge of the abutment where we suspected the origin could be, and areas of the fractured zirconia zone covered with porcelain (stars). Gold-sputter and green stain were used to highlight the topography.

EDS AND SEM ANALYSES

EDS analysis did not show unusual chemical elements in the dental ceramics used. Therefore, this excluded contamination as a possible reason for fracture. It also confirmed the presence of chemical elements of both the veneering ceramic and zirconia, such as oxygen, aluminum, potassium, sodium, zirconia, and silicon *(Figure 3)*. The shiny portions on the zirconia abutment fractured surfaces showed the presence of the same elements, confirming the presence of porcelain between the broken surfaces of the abutment.

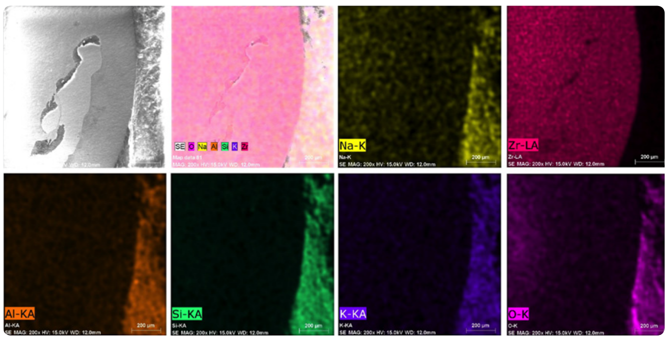

Figure 3: EDS mapping indicating the presence of chemical elements of both the veneering ceramic and zirconia, such as oxygen, aluminum, potassium, sodium, zirconia, and silica. No traces of contaminant agents were noted.

SEM analysis of the fragments also showed the existence of thin portions of porcelain between the two surfaces. Pores of various sizes were observed in the veneering ceramic as well as wake (a trail surrounding a buble or discontinuity) and twist hackles (region where the tensile stress tilted from crack surface). Hackles are useful fracture marks that indicate the direction of crack propagation. The larger pores of veneering ceramic did not exceed 6 µm in diameter. The presence of a concave region in the inner edge of the pillar was noted and arrest lines were soon detected (a sharp line on the fracture surface where crack stopped momentarily and continued under a more or less altered stress configuration) *(Figure 4)*. Aditionally, the existence of a compression curl (an important sign that the specimen either was loaded primarily in bending or had a strong bending component) indicated that the origin was in the inner edge, away from the concave region *(Figure 4)*. The crack path direction was from palatal to proximal and buccal sides of the crown. Abutment fracture occurred well above the transition area between the metallic insertion and zirconia portion *(Figure 2a)*.

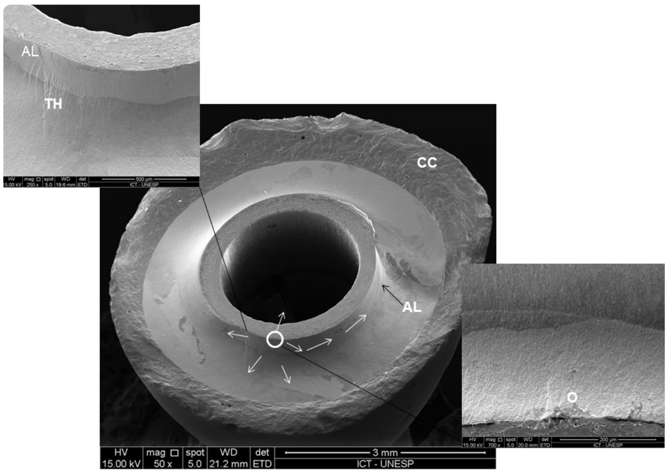

Figure 4: SEM images of the cervical fragment showing the direction of crack propagation (white arrows),compression curl (CC), arrest lines (black arrow) encompassing the originating defect in the inner edge (circle), and twist hackles (TH). An approximate view (700 x) of the originating defect (O) is also shown.

DISCUSSION

Failures related to frameworks are rare in zirconia-based restorations and chipping of layering porcelain is the main cause of technical complication.[11,19] However, the results of the present analysis indicated the origin was an acute defect on the inner edge of the abutment, at the cervical region.

The flaws in dental ceramic prostheses are generally associated with structural defects. These defects can occur naturally in the material or as a result of the stages of manufacturing.[23] The defect seen in the present analysis was probably impinged on the abutment after manufacturing. These types of defects propagate under loading. Because teeth crown was not subjected to masticatory forces, since the fracture occurred at the time of insertion, the loading produced during torqueing was enough to fracture the crown.

In the case described here, the axial walls of the abutment had adequate thickness, excluding the possibility of early failure due to over-reduction of these walls.[12] However, the abutment was reshaped palatally before veneering, and during this adjustment copious irrigation was applied to prevent overheating of the abutment. The presence of bur undercuts were not noticed of the fractured surfaces, but this portion of the abutment became naturally thiner.

Moreover, from the clinical images, the fracture occurred in a region where the amount of porcelain was abruptly increased in thickness, which may have caused considerable residual thermal stress[24] that can facilitate crack propagation. During firing, the thin zirconia wall cracked, and the porcelain may have infiltrated it. A small amount of force during torqueing was then enough to break the abutment. Therefore, it is likely that customization of the abutment in concert with residual thermal stress facilitated crack propagation from an internal defect in the abutment. In fact, customization of the zirconia abutment, either with burs or porcelain, is a common procedure and, according to our observations, needs to be done carefully.

A recent *in vitro* fractograpahic analsys of zirconia abutments showed the factures started in the cervical region, close to screw head.[25] It was demonstrated the design of the implant is important to avoid fracture. We must say not only the desing of abutments should be taken into consideration but also the customization process before veneering. We believe that this type of report can be of assistance during the planning of implant supported porcelain crown with a zirconia abutment, because either an early failure or a failure that occurs after some usage present one origin, but several failure modes.

CONCLUSIONS

Evaluation of clinical records and fractographic analysis of this case report revealed that the failure was probably related to a small acute defect on the inner part of the abutment at the cervical region. This defect extended due to, loading (torqueing), residual thermal stresses after the veneering process and the presence of porcelain in the zirconia abutment.

MANUFACTURES DETAILS

- NobelReplace™, Nobel Biocare Brasil, São Paulo, SP, Brazil
- NobelProcera™ Abutment Zirconia MZ, Nobel Biocare Brasil, São Paulo, SP, Brazil
- Vita VM™9, VITA Zahnfabrik, H. Rauter GmbH & Co. KG, Bad Säckingen, Germany
- Vita Akzent, VITA Zahnfabrik, H. Rauter GmbH & Co. KG, Bad Säckingen, Germany

- Digital Dental Ultrasonic CD-4820, Shenzhen Codyson Electrical Ltd, Guangdong, China
- Zeiss Discovery V20, Zeiss, Göttingen, Germany
- Paper Mate® Flair M, Atlanta, GA, USA
- Quantax EDS for SEM, Bruker Corporation, Billerica, MA. USA
- Emitech SC7620, Quorum Technologies Ltd, Laughton, UK
- INSPECT S50, FEI, Brno, Czech Republic

REFERENCES

1. Bidra AS, Rungruanganunt P. Clinical outcomes of implant abutments in the anterior region: a systematic review. *J. Estht. Rest. Dent.*, 2013;**25**:159.176.
2. Yildirim M, Fischer H, Marx R, Edelhoff D. In vivo fracture resistance of implant-supported all ceramic restorations. *J. Prosthet. Dent.*, 2003;**90**:325.331.
3. Guess CP, Att W, Strub JR. Zirconia in fixed implant prosthodontics. *Clinic. Impl. Dent. Rel. Res.*, 2012;**14**:633.645.
4. Kosmac T, Oblak C, Jevnikar P, Funduk N, Marion L. The effect of surface grinding and sandblasting on flexural strength and reliability of Y-TZP zirconia ceramic. *Dent. Mater.*, 1999; **15**:426.433.
5. Kosmac T, Oblak C, Jevnikar P, Funduk N, Marion L. Strength and reliability of surface treated Y-TZP dental ceramics. *J. Biomed. Mater. Res.*, 2000;**53**:304.313.
6. Luthardt RG *et al*: Reliability and properties of ground Y-TZP-zirconia ceramics. *J. Dent. Res.*, 2002;**81**:487.491.
7. Zhang Y, Lawn B, Rekow ED, Thompson VP: Effect of sandblasting on the long-term performance of dental ceramics. *J. Biomed. Mater. Res.* Part. B: Appl. Biomater., 2004;**71**:381.386.
8. Guazzato M, Quach L, Albakry M, Swain MV. Influence of surface and heat treatments on the flexural strength of Y-TZP dental ceramic. *J. Dent.*, 2005;**33**:9.18.
9. Zembic A, Sailer I, Jung RE, Hammerle CH. Randomized controlled clinical trial of customized zirconia and titanium implant abutments for single-tooth implants in canine and posterior regions: 3-year results. *Clin. Oral. Implants. Res.*, 2009; **20**:802.808.
10. Zembic A, Bosch A, Jung RE, Hammerle CH, Sailer I. Five-year results of a randomized controlled clinical trial comparing zirconia and titanium abutments supporting single-implant crowns in canine and posterior regions. *Clin. Oral. Implants. Res.*, 2013; **24**:384.390.
11. Zembic A, Philipp AO, Hämmerle CH, Wohlwend A, Sailer I. Eleven-year follow-up of a prospective study of zirconia implant abutments supporting single all-ceramic crowns in anterior and premolar regions. *Clin. Implant. Dent. Relat. Res.*, 2015 Oct;17 Suppl 2:e 417.426. doi: 10.1111/cid.12263.
12. Aboushelib MN, Salameh Z. Zirconia implant abutment fracture: clinical case reports and precautions for use. *Int. J. Prosthodont.*, 2009;**22**:616.619.
13. Yildirim M, Fischer H, Marx R, Edelhoff D. In vivo fracture resistance of implant-supported all-ceramic restorations. *J. Prosthet. Dent.*, 2000;**90**:325.331.
14. Mitsias, ME: Fatigue test analysis of two esthetic implant abutments. MS, New York, NY. 2004; p1.92.
15. Maeda Y, Satoh T, Sogo M: In Vitro differences of stress concentrations for internal and external hex implant-abutment connections: a short communication. *J. Oral. Rehabil.*, 2006;**33**:75.78.
16. Khraisat A, Stegaroiu R, Nomura S, Miyakawa O. Fatigue resistance of two implant/abutment joint designs. *J. Prosthet. Dent.*, 2002;**88**:604.610.
17. Sailer I, Sailer T, Stawarczyk B, Jung RE, Hämmerle CHF. In vitro study of the influence of the type of connection on the fracture load of zirconia abutments with internal and external implant-abutment connections. *Int. J. Oral. Maxillofac. Implants.*, 2009;**24**:850.858.
18. Alqahtani F,Flinton R. Postfatigue fracture resistance of modified prefabricated zirconia implant abutments. *J. Prosthet. Dent.*, 2014;**112**:299.305.
19. Ekfeldt A, Fürst B, Carlsson EG. Zirconia abutments for single-tooth implant restorations: a retrospective and clinical follow-up study. *Clin. Oral. Impl. Res.*, 2011;**22**:1308.1314.
20. Scherrer SS, Quinn GD, Quinn JB. Fractographic failure analysis of a Procera AllCeram crown using stereo and scanning electron microscopy. *Dent. Mater.*, 2008 Aug; **24**:1107.1113. doi: 10.1016/j.dental.2008.01.002.
21. Quinn, GD. Fractography of ceramics and glasses. *A NIST recommended practice guide*; Special Publication 960-16; Washington, DC: National Institute of Standards and Technology; May 2007 (http://www.ceramics.nist.gov/pubs/practice.htm).
22. ASTM C1322-15, Standard Practice for Fractography and Characterization of Fracture Origins in Advanced Ceramics, ASTM International, West Conshohocken, PA, 2015, www.astm.org. doi: 10.1520/C1322-15.
23. Denry I. How and when does fabrication damage adversely affect the clinical performance of ceramic restorations? *Dent. Mater.*, 2013;**29**:85.96.
24. Inokoshi M *et al*. Structural and chemical analysis of the zirconia-veneering ceramic interface. *J. Dent. Res.*, 2016 Jan;**95**:102.109. doi: 10.1177/0022034515608825.
25. Gargarella P *et al*. Phase formation, thermal stability and mechanical properties of a Cu-Al-Ni-Mn shape memory alloy prepared by selective laser melting. *Mater. Res.*, 2015;**18**:35.38.