THE JOURNAL OF PROSTHETIC DENTISTRY

CLINICAL REPORT

Premature failure of a screw-retained ceramic single crown: A clinical report and fractographic analysis

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ABSTRACT

Screw-retained implant-supported ceramic restorations have shown increased rates of technical complications compared with their cemented counterparts, including fracture and chipping of the ceramic structures. The present clinical report identified the causes leading to the catastrophic failure of a screw-retained lithium disilicate veneered crown cemented to a zirconia abutment with a titanium base by using a systematic fractographic approach. A combination of occlusal overloading, a deficient design and inadequate material selection was identified as being responsible for the fracture. These findings highlight the importance of a thorough analysis of the anatomic conditions and loading scenario of screw-retained implant-supported restorations. (J Prosthet Dent 2022;127:32-7)

Posterior ceramic restorations have become increasingly popular in recent decades as a result of higher esthetic demand. The development of zirconia implant abutments with a titanium base has also improved optical properties in high-load-bearing areas.[1] Surgical and restorative advances have facilitated the use of screw-retained systems in single-unit implant-supported restorations, which reduces the risk of the biologic complications associated with excess cement around the implant platform.[2,3] However, higher fracture rates have been observed for screw-retained implant-supported restorations,[4] mainly because the screw access hole weakens the ceramic structure,[5-7] especially in bilayer restorations.[8] In addition, difficulties encountered in the long-term success of adhesive bonding to zirconia substrates[9,10] can affect the homogeneous distribution of stress to the underlying abutment. Consequently, the design, material selection, and fabrication of screw-retained implant-supported restorations are demanding and technically sensitive processes.[4]

Although the fracture and chipping of ceramic restorations have been reported to be a relatively common event,[11] causes leading to their occurrence are rarely investigated by clinicians. In vitro studies have identified material issues[12] and shortcomings during the manufacturing processes[13] as the main causes of ceramic fractures. However, the analysis of clinically failed restorations becomes a far more challenging task. In recent years, the use of fractography has proven to be a powerful tool for assessing the causes that originated the fracture of a ceramic restoration or component.[14] Fractography interprets the microscopic features on the fractured surfaces to trace back the origin of the fracture,[15] which leads in turn to a better understanding of the failure process and causes. Examples of fractography applied to explain clinical failures have been reported for ceramic crowns,[16-18] multiple-unit fixed dental prostheses,[19] as well as abutments[20] and implants.[21,22]

The purpose of this clinical report was to identify the causes of the premature failure of a screw-retained lithium disilicate (IPS e.max) restoration cemented to a zirconia abutment with a titanium base by using a systematic fractographic approach.

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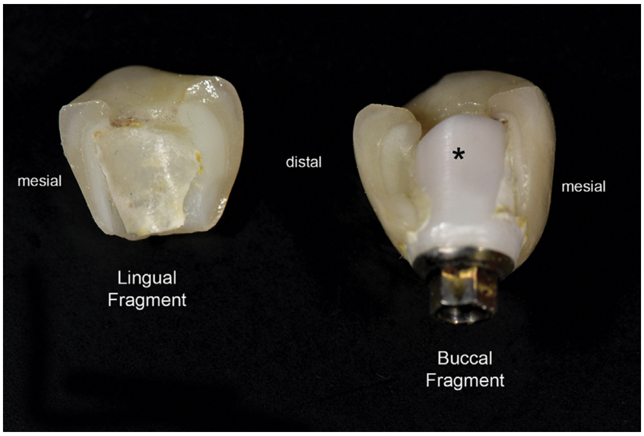

Figure 1. Retrieved fragments. Note clean appearance of zirconia abutment (*), with no signs of resin cement on surface.

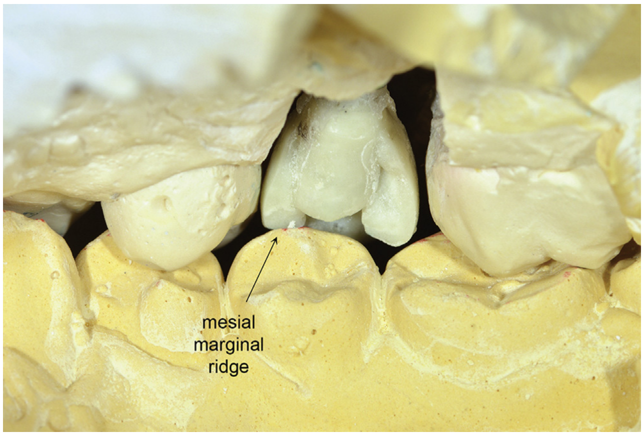

Figure 2. Palatal view of replica screwed to definitive casts. Fracture origin located at mesial marginal ridge area, which underwent heavy occlusion with antagonist's buccal cusp.

CLINICAL REPORT

A 22-year-old woman with a noncontributory medical history presented to the dental practice with a fractured maxillary right second premolar implant-supported crown. No parafunctional habits or occlusal disease were detected. The same clinician had placed the restoration less than 6 months previously. She reported no signs or symptoms before the catastrophic event when the crown split into 2 halves during mastication.

The fractured crown was a screw-retained ceramic restoration with a lithium disilicate coping (IPS e.max Press; Ivoclar Vivadent AG) veneered with a fluorapatite glass-ceramic (IPS e.max Ceram; Ivoclar Vivadent AG) extraorally cemented with a dual-polymerizing resin cement (Panavia V5; Kuraray Noritake Dental Inc) to a zirconia abutment with a titanium base (Legacy 0°; Implant Direct). Surface treatment of the zirconia surface consisted only of the application of a 10-methacryloyloxydecyl dihydrogen phosphate (MDP) primer (Clearfil Ceramic Primer Plus; Kuraray Noritake Dental Inc) without airborne-particle abrasion or another pretreatment. The intaglio surface of the lithium disilicate crown was etched with hydrofluoric acid for 20 seconds, thoroughly rinsed with water, and dried before the application of a silane coupling agent (Monobond N; Ivoclar Vivadent AG). Occlusal adjustment followed the implant-protective occlusion concept.[23] Sequential polishing with diamond polishers (CeraMaster; Shofu Dental Corp) was conducted to remove damage introduced during the adjustment process. A radiograph determined acceptable implant-crown fit before the restoration was screwed to the implant (3.8 × 10.5 mm Tapered Internal; BioHorizons).

After the examination, the abutment with the buccal fragment of the crown still attached was removed and an interim restoration placed. She had recovered the palatal fragment and brought it to the dental appointment. Because of time restrictions, no clinical pictures were made, but the retrieved portions of the crown were photographed (Fig. 1). An extraoral impression of the buccal fragment still cemented to the abutment was made with a light-body hydrophilic siloxane material (Panasil initial contact X-Light; Kettenbach GmbH & Co KG) in combination with a putty-base silicone (Panasil Soft Putty; Kettenbach GmbH & Co KG). The impression was poured with a high-accuracy polyurethane material (AlphaDie MF; Schütz Dental GmbH) to obtain a replica,[24] which was used for the analysis on the definitive casts (Fig. 2). The zirconia abutment with a titanium base was then carefully detached from the remaining lithium disilicate crown by sectioning multiple times. The zirconia offered a clean surface after the removal of the lithium disilicate coping, with no resin cement apparent on the surface, as shown in Figure 1. The retrieved abutment was used to fabricate a new monolithic lithium disilicate (IPS e.max Press; Ivoclar Vivadent AG) crown with no screw-access channel and therefore directly cemented intraorally to the zirconia abutment.

Both retrieved fragments were ultrasonically cleaned in ethanol and then examined under a stereomicroscope (SMZ10; Nikon Corp) at ×40 magnification to map the areas of interest. After gold coating, fractographic features in the fractured surfaces were analyzed with a scanning electron microscope (TESCAN VEGA II LSH; TESCAN ORSAY HOLDING a.s.). Characteristic markings (arrest lines) below the mesial marginal ridge of the palatal fragment (Fig. 3) were used to trace back the potential fracture origin, located close to the contour wall of the screw access hole. The presence of a thick veneer layer in this area, insufficiently supported by a thin coping (about 0.5 mm), further supported this hypothesis. A higher magnification micrograph confirmed the match between the center of the concentric arrest lines and the potential origin region (Fig. 4). The direction of

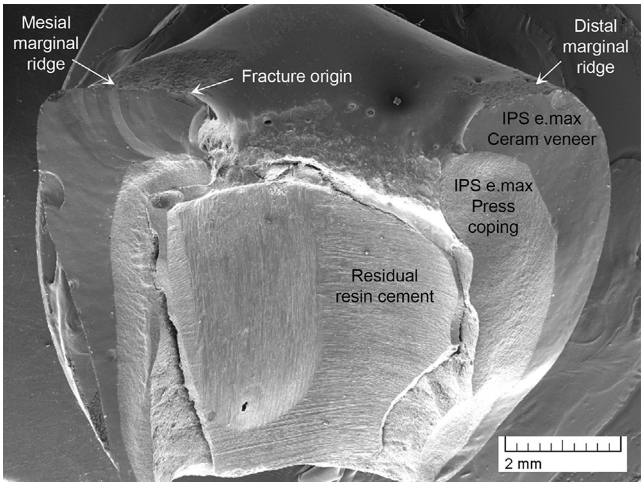

Figure 3. Scanning electron micrograph of palatal fragment, displaying fracture origin close to wall of screw access hole. Original magnification ×18.

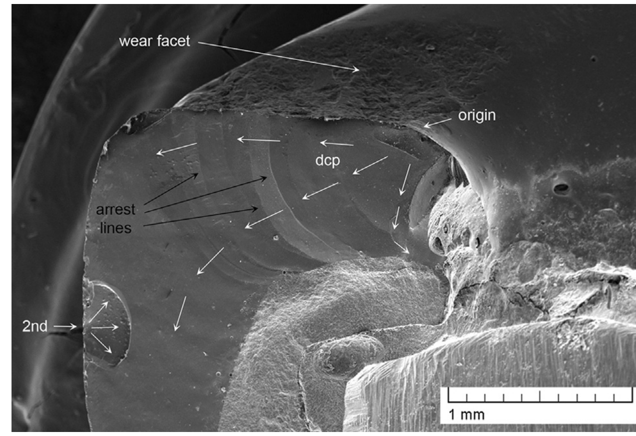

Figure 4. Scanning electron micrograph of mesial marginal ridge of palatal fragment. Arrest lines on fractured surface identify direction of crack propagation (dcp). Extensive wear damage visible on marginal ridge surface. At mesial contour wall of crown secondary fracture event (2nd) indicated, probably related to interproximal contact adjustment. Original magnification ×58.

crack propagation was confirmed by wake hackle emanating from pores in the veneer and twist hackle close to the interface of the veneer and the coping (Fig. 5). A close observation of the origin region (Fig. 6) revealed a series of defects corresponding to surface scratches and subsurface microcracks in this area. Concentration of occlusal loads in the mesial marginal ridge (Fig. 2) appeared to have triggered the onset of the fracture from these subsurface cracks, which then propagated in the cervical direction through the veneer layer and passed to the thin lithium disilicate coping. Failure of the adhesive bond to the zirconia abutment shifted the stress concentration to the distal portion of the crown, ultimately leading to the complete detachment of the palatal cusp. Fractographic markings on the distal area of the palatal fragment (Fig. 7) confirmed this crack propagation path.

DISCUSSION

The presence of a screw access hole has been reported to weaken the restoration, as the continuity of the structure is disrupted.[5,6] This becomes of special relevance for restorations with small occlusal tables, such as the premolar of the current clinical report. As depicted in Figure 1, the screw-access hole extended over one half of the total occlusal area of the crown, leaving minimal material volume in the marginal ridges to support masticatory forces. Consequently, stress accumulation in these areas triggered the propagation of cracks from surface damage in the glass-ceramic (Fig. 6). The crack onset was further favored in the mesial ridge of the crown by the choice of a bilayer system instead of a monolithic solution and a poorly designed lithium disilicate framework. From Figure 3, it is clear that the coping had an insufficient thickness in the mesial ridge area (about 0.5 mm), in spite of the manufacturer's recommendation of a minimum 0.8 mm for lithium disilicate frameworks in posterior restorations.[25] Furthermore, for a specific overall thickness of 1.8 mm (as displayed by the crown in Fig. 3 in this area), the recommendation is to design a framework with at least a 1-mm thickness.[25] Loading stresses at the mesial marginal ridge were sustained to a high extent by the weaker veneer layer, ultimately leading to crack propagation once the fracture toughness of the material was exceeded. Indication of a monolithic solution, using tougher materials such as zirconia or lithium disilicate, would have reduced the risk of catastrophic failure,[8] increasing the restoration lifetime.

The presence of a heavy occlusal contact with the buccal cusp of the natural antagonist premolar (Fig. 2) further contributed to stress concentration in the fracture origin area. Because of the lack of periodontal ligament, dental implants are prone to develop occlusal overloading, jeopardizing the complete implant-restoration system. To compensate for the mobility discrepancy between teeth and implants, the implant-protective occlusion concept[23] was applied here, leaving only a light contact at heavy closure and no contact in light occlusion. Nevertheless, implants have been reported to develop sustained increments in their occlusal load over time, as well as changes to the occlusal contacts present at the insertion of the restoration.[26,27] The large wear facet across the marginal ridge surface observed in Figure 4 confirms this self-adjustment process. Abrasion of the glassy veneer was caused by the antagonist's buccal cusp, which also introduced fatigue wear microcracks into the

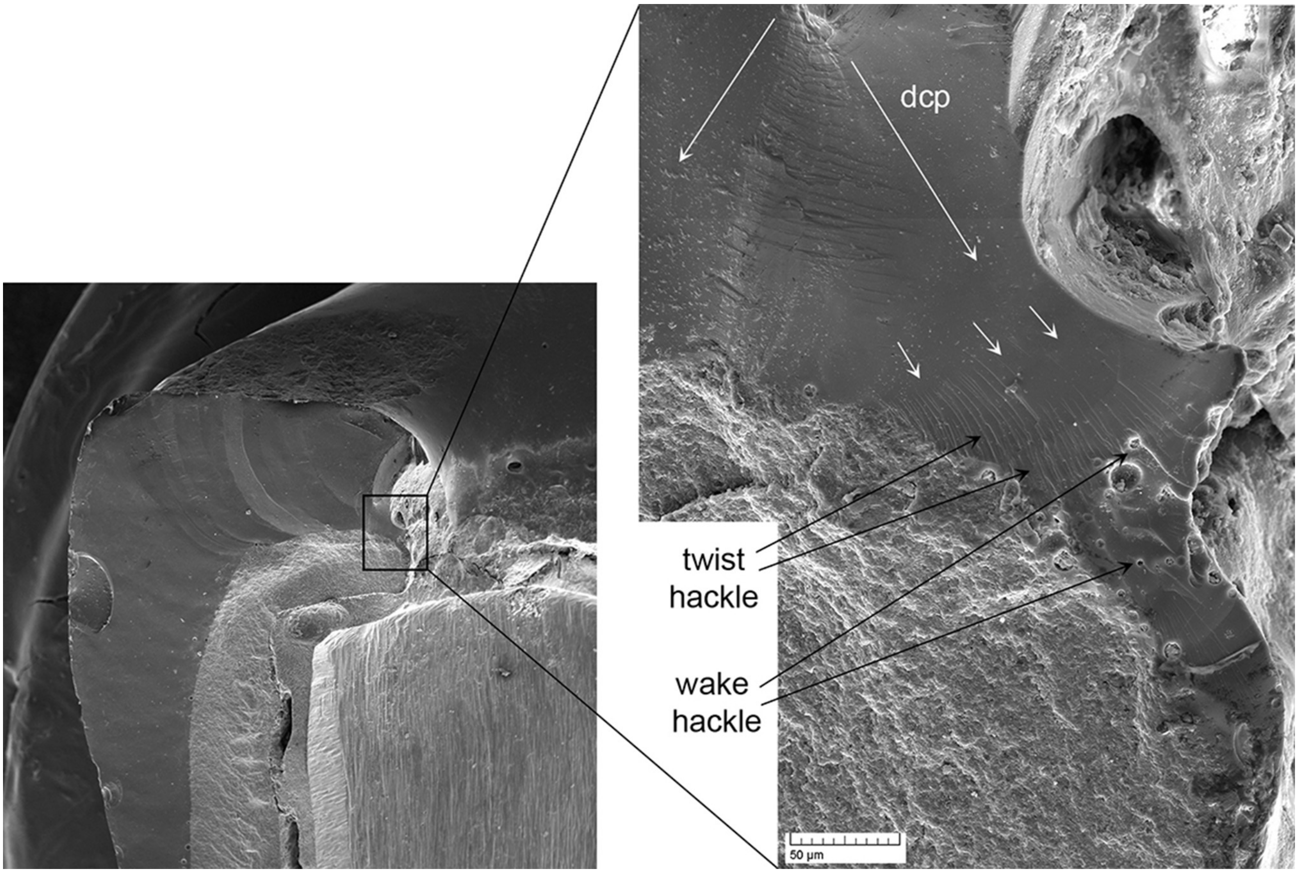

Figure 5. Higher magnification scanning electron micrograph of mesial marginal ridge of palatal fragment displaying occlusocervical direction of crack propagation (dcp), identified by wake hackle and twist hackle close to interface between veneer layer and coping. Original magnification: overview ×58; inset ×850.

subsurface (black arrows in the inset of Fig. 6). Thus, a combination of overloading and subsurface microcracking was responsible for the initiation and propagation of the catastrophic crack.

Another aspect that needs consideration is the poor quality of the adhesive bond between the resin cement and the zirconia abutment, evidenced by the clean appearance of the exposed material (Fig. 1). The sole use of the MDP-containing primer failed to prevent detachment of the lithium disilicate framework from the zirconia once the crack started to propagate from the mesial ridge, ultimately leading to the complete splitting of the palatal cusp. In spite of the good in vitro results of MDP-containing primers and resin cements in enhancing the bond strength to zirconia, concern has been raised regarding the long-term reliability of this bond.[9,10] To enhance the stability of the bond and reduce the risk of hydrolytic degradation, mechanical pretreatment of the zirconia surface (by using alumina airborne-particle abrasion or tribochemical silica coating) has been recommended before the application of the MDP-

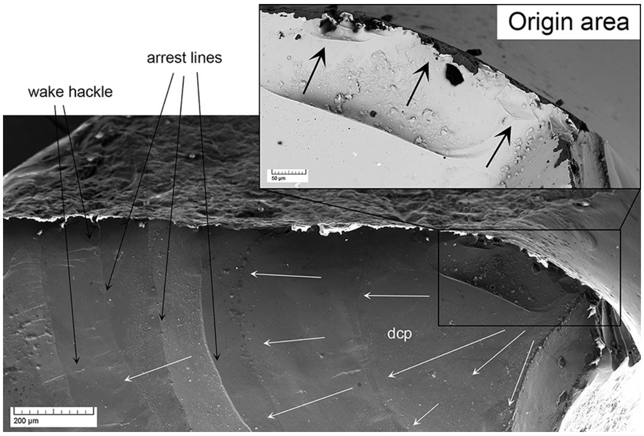

Figure 6. High-magnification scanning electron micrograph of mesial marginal ridge of palatal fragment where concentric arrest lines and wake hackle enabled fracture origin traced back to subsurface area of glassy veneer. Higher magnification scanning electron micrograph (back-scattered mode) of origin area shows extent of subsurface cracks (*black arrows*), responsible for fracture onset that led to catastrophic failure of the crown. Original magnifications: overview ×250; inset ×652.

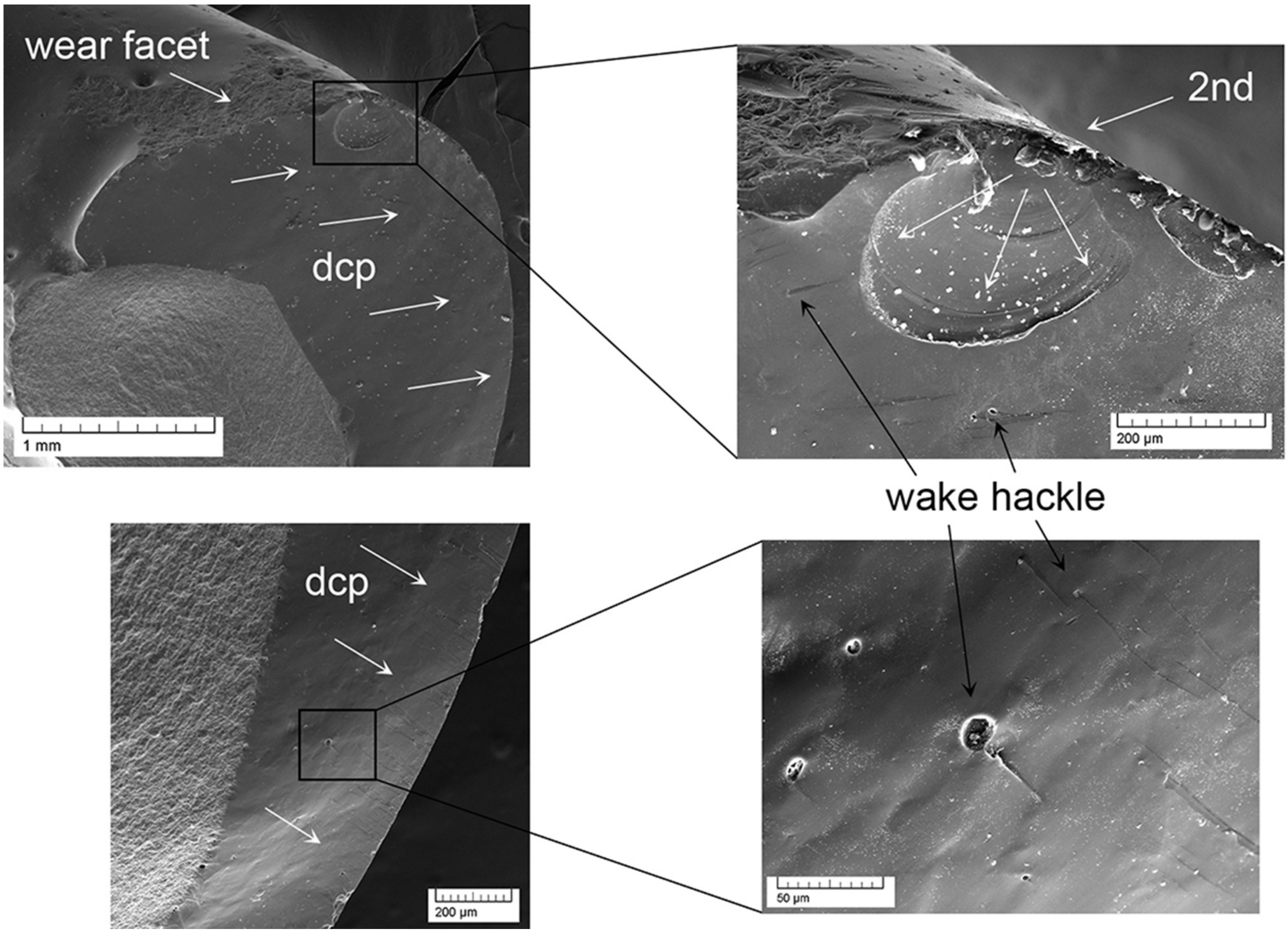

Figure 7. Scanning electron micrograph of 2 areas of distal marginal ridge of palatal fragment. Shallower wear facet distinguishable at marginal ridge veneer surface, where secondary fracture event (2nd) was not related to catastrophic fracture. Fractographic marks in fractured surfaces coincide with general direction of crack propagation (dcp), from mesial to distal, as crack finished splitting the crown. Original magnifications: upper overview ×58; upper inset ×250; lower overview ×140; lower inset ×854.

containing primer/resin cement.[10] Accordingly, the manufacturer of Panavia V5 recommends airborne-particle abrasion for the pretreatment of the zirconia surfaces. This was, however, not followed here by the clinician during the cementation step. Mechanical pre-treatment may not have prevented the fracture of the restoration, but it is possible that it would have at least delayed its occurrence.

The decision to use screw retention instead of a cemented restoration resulted critical for the catastrophic outcome of this case. Benefits of screw retention include ease of retrieval and better control of the cementation line;[4] however, anatomic and occlusal conditions described here should have contraindicated its use. Moreover, the incorrect choice of a bilayer restoration instead of a monolithic crown and the deficient design of its coping emphasize the need for comprehensive treatment planning and communication with the dental laboratory technician for the success of this type of restoration.

SUMMARY

The causes of the premature failure of a screw-retained implant-supported ceramic restoration were assessed using a systematic fractographic approach. A deficient restoration design in combination with occlusal over-loading in the mesial marginal ridge led to the onset of the fracture and the catastrophic failure of the restoration.

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Acknowledgments
The authors thank Dr Renan Belli for the fruitful discussions on the fractographic results and their analysis.

https://doi.org/10.1016/j.prosdent.2020.06.025