Zirconia-Based Screw-Retained Prostheses Supported by Implants: A Retrospective Study on Technical Complications and Failures

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ABSTRACT

Background: Little information is yet available on zirconia-based prostheses supported by implants.

Purpose: To evaluate technical problems and failures of implant-supported zirconia-based prostheses with exclusive screw-retention.

Material and Methods: Consecutive patients received screw-retained zirconia-based prostheses supported by implants and were followed over a time period of 5 years. The implant placement and prosthetic rehabilitation were performed in one clinical setting, and all patients participated in the maintenance program. The treatment comprised single crowns (SCs) and fixed dental prostheses (FDPs) of three to 12 units. Screw-retention of the CAD/CAM-fabricated SCs and FDPs was performed with direct connection at the implant level. The primary outcome was the complete failure of zirconia-based prostheses; outcome measures were fracture of the framework or extensive chipping resulting in the need for refabrication. A life table analysis was performed, the cumulative survival rate (CSR) calculated, and a Kaplan-Meier curve drawn.

Results: Two hundred and ninety-four implants supported 156 zirconia-based prostheses in 95 patients (52 men, 43 women, average age 59.1 ± 11.7 years). Sixty-five SCs and 91 FDPs were identified, comprising a total of 441 units. Fractures of the zirconia framework and extensive chipping resulted in refabrication of nine prostheses. Nearly all the prostheses (94.2%) remained in situ during the observation period. The 5-year CSR was 90.5%, and 41 prostheses (14 SCs, 27 FDPs) comprising 113 units survived for an observation time of more than 5 years. Six SCs exhibited screw loosening, and polishing of minor chipping was required for five prostheses.

Conclusions: This study shows that zirconia-based implant-supported fixed prostheses exhibit satisfactory treatment outcomes and that screw-retention directly at the implant level is feasible.

KEY WORDS: implant, screw-retention, fixed implant prostheses, zirconia

INTRODUCTION

Porcelain-fused-to-metal (PFM) prostheses have been well accepted for many years, and this technique is considered the "gold standard" in fixed prosthodontics. It appears that they are still superior to all-ceramic restorations.[1] However, patients often ask for metal-free restorations and want the most aesthetic treatment outcome, resulting in an increasing replacement of PFM by ceramics. Due to good aesthetics and favorable biological properties, ceramic materials such as leucite-reinforced ceramics and lithium disilicate have become popular and have been used to restore teeth with single

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DOI 10.1111/cid.12214

crowns or veneers. These materials have now been in use for more than 10 years and are well documented in the literature.[2] Adhesive cementation enhances the mechanical properties of these materials. Nevertheless, there are clear limits to prosthetic indications for this type of metal-free restoration.

The high physical strength of yttria-stabilized tetragonal zirconia polycrystal (Y-TZP, hereafter referred to as zirconia) eventually led to broader applications of full-ceramic restorations, which became available for three- to five-unit fixed dental prostheses (FDPs) cemented on teeth or on titanium implant abutments.[3,4] Initially, the risk of fractures resulted in a limited size of framework extensions, and the computer-assisted design/manufacturing (CAD/CAM) systems did not have the capacity to produce bridges with long spans. More than two pontics per framework was mostly not recommended,[3,5] and a defined proximal connector surface (3×3 mm to 4×4 mm) was required to obtain sufficient stability.[6] There is some controversy in the discussion on precision of fit of these tooth-retained prostheses.[4,7]

In parallel to the application of zirconia for tooth-borne restorations, zirconia implant abutments were fabricated to be used for cemented restorations or with direct veneering for screw-retained single crowns (SCs).[8] Nowadays, most implant systems offer individually designed milled abutments. Recent studies have confirmed comparable outcomes regarding biological or technical aspects whether titanium or zirconia abutments are used.[9–11]

Currently, the dental market for zirconia is growing in parallel with the development of refined and efficient computer software and hardware for production of zirconia restorations. The number of clinical investigations on zirconia-based FDPs cemented on teeth and titanium implant abutments has increased rapidly.[3,6,12–16] These studies still exhibit a rather low number of patients and prostheses with a limited observation time. Various studies have reported on technical complications such as chipping of the veneering ceramics and loss of retention, some of them being related to biological aspects of abutment teeth.[13,14,16–18] Thus, attitudes toward the integration of zirconia-based FDP in the daily treatment concepts remain skeptical, which could be explained by the variety of scientific reports and laboratory investigations on material fractures, stress, and crack propagation.[5,6,17,19]

So far, most information on zirconia-based prostheses comes from studies on teeth and, less frequently, on cement-retained implant prostheses. Presently, no data are available that deal with the various technical aspects of screw-retained FDPs on implants. One early short-term study focusing on zirconia-based FDPs included screw-retention.[20]

Thus, a major problem from a restorative point of view – as reflected in the recent literature mentioned above – seems to be the mechanical stability of the zirconia frameworks and the veneering ceramics. Therefore, the aim of this case series was to identify technical failures and complications of zirconia-based, implant-supported, screw-retained SCs and FDPs.

MATERIALS AND METHODS

Patients and Implants

During a time period from 2005 to 2010 patients with partial edentulism or edentulous jaws were consecutively admitted for implant placement and zirconia-based prosthetic treatment. The surgical and prosthetic treatment was carried out in one clinical setting within the university, and the patients were regularly followed up after completion of the treatment. This retrospective survey was part of a quality control assessment of the dental consultation and meets the standards of the Declaration of Helsinki.

Eligible patients were informed about the entire treatment and in particular about the material to be used for restoration. They completed the informed consent form and confirmed that they were willing to have zirconia-based prostheses placed instead of conventional PFM restorations. They were also informed that they should follow the maintenance care program, with at least one or two scheduled visits per year. The patients covered the costs for the treatment themselves, but they were informed that in case of failures of the zirconia-based prostheses, the fabrication of new restorations would be free of charge.

One person performed the patient recruitment, and patients of all age groups with different dentitions and different levels of complexity of implant surgery required were admitted if they met the inclusion criteria. Reasons for exclusion were as follows:

- Regular medication with corticosteroids
- Poorly controlled diabetes mellitus
- Heart attack/stroke within the last 6 months

- Any disease that would not allow placement of implants under local anesthesia
- Psychiatric problems
- Unrealistic expectations
- Pregnancy
- History of oral tumor resection and/or radiotherapy/chemotherapy

Heavy smokers – although few among these patients – were informed about the possible negative influence of smoking on treatment outcome, and a smoking cessation program was proposed under supervision of the clinic. They were free to accept and follow it or not.

After surgery, healing time was 6 weeks in the mandible and 8 to 10 weeks in the maxilla. If the surgical implant placement was combined with local bone augmentation techniques or sinus floor elevations with a lateral window, the healing period was 4 to 6 months. NobelReplace® Tapered implants (Nobel Biocare, Kloten, Switzerland) were used.

Zirconia-Based Prostheses

Patients with SCs and FDPs of three units up to full-arch FDPs of 12 units were accepted for treatment. The primary goal was direct screw-retention at the implant level. Setups and surgical splints were used for optimum implant placement with regard to the axis orientation and to properly locate the access hole for screw-retention. Three-dimensional computer analysis with the NobelGuide software (Nobel Biocare) was used for planning of large frameworks and if complex anatomical configurations or limitations in available bone were identified.[21]

Impression taking was done by the pickup technique, with well-fitting individual open trays and screw-retained transfer copings. Splinting of the transfer copings was only used for the fabrication of large cross-arch prostheses of 6 to 12 units. The impression material was hard polyether (Impregum, 3M ESPE, Rüschlikon, Switzerland). WAX/CAM technology was applied by the laboratory technician. He fabricated a resin pattern or wax form for scanning, and its design was completed by means of the computer software. The milling (CAM) process was carried out on the basis of these electronic data. The veneering of the frameworks was completed, with layered feldspathic ceramics for all restorations. The CAD/CAM system was Procera™ (Nobel Biocare). The technical concept of Procera provides engaging, antirotational function by means of a titanium insert for screw-retention of SCs, while FDPs are nonengaging, meaning without the insert. Both SCs and FDPs had a flat-to-flat contact zone between the zirconia framework and implant shoulder (Figures 1–3, A and B).

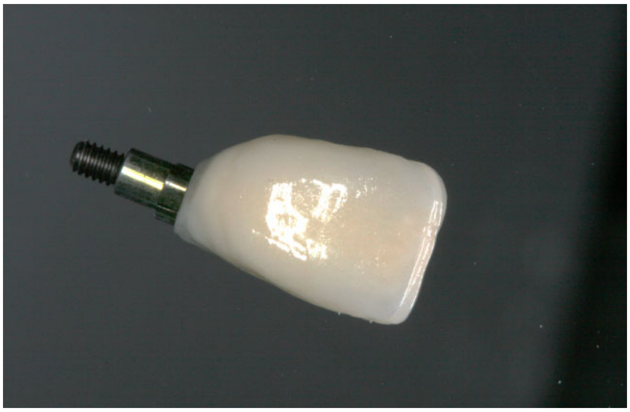

Figure 1 Single crown, screw-retained with a titanium insert, engaging.

All patients were included in the regular maintenance care program, with one or two scheduled visits per year when their treatment was completed.

Data Collection

All patients were recalled in the year 2012, and two independent investigators collected all patients' data. All additional information was obtained from the patient charts and separate records that had been kept by the dental laboratory. At this time, the observation time ranged from 2 to maximum 7 years.

Figure 2 Four-unit FDP, screw-retained, non-engaging.

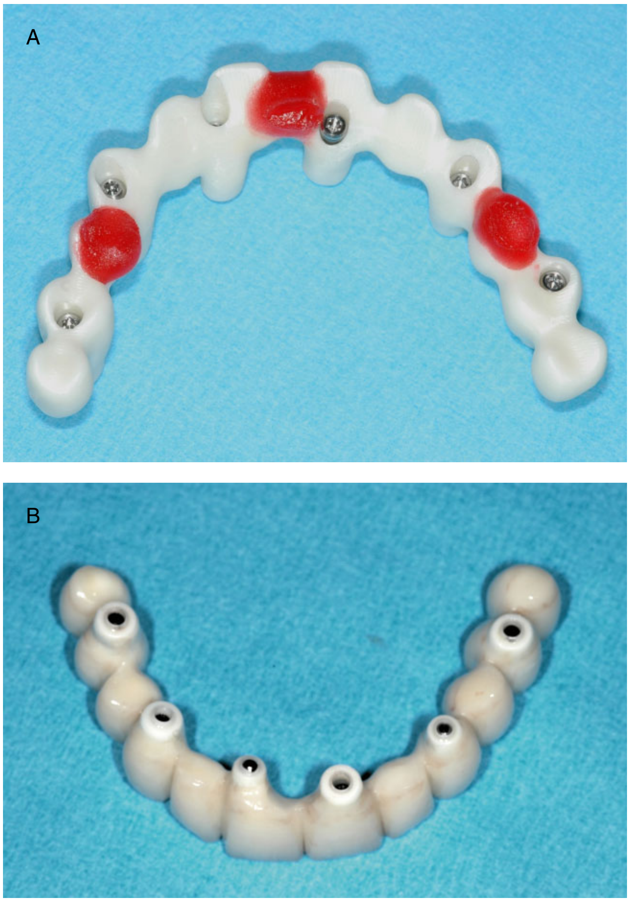

Figure 3 *A*, Zirconia framework with occlusal stops of pattern resin. *B*, After veneering.

The primary outcome was the survival of the zirconia-based prostheses. The outcome measure was fracture of the framework or large chipping of the veneering material resulting in the need for a complete refabrication of the prosthesis. The secondary outcome was technical complications that necessitated maintenance services for the zirconia prostheses, such as minor chipping necessitating polishing, as well as loosening of the occlusal screw followed by tightening and loosening of the titanium insert of a single crown resulting in the need for replacement of the insert. Loss of the prosthesis due to implant loss was also recorded.

Statistical Analysis

Descriptive statistics were used for patients' demographics, implant distribution, type of zirconia reconstruction, and complications. Censored data were utilized for statistical calculations. A survival analysis[22] was performed for zirconia prostheses and expressed in the cumulative survival rate (CSR). The Kaplan-Meier curve depicts the probability of failures followed by refabrication of the prosthesis or complications requiring maintenance service.

RESULTS

Ninety-five patients (52 men, 43 women, average age 59.1 ± 11.7 years) were included in the present sample. Five out of them were not available in the year 2012. One patient had died, two patients returned to their private dentist, and one patient had dropped out for unknown reasons. Their records were kept in the data up to the date they dropped out. One elderly female patient could not attend the recall session in 2012 due to illness. Her data were continuously recorded until the end of 2011, including one failure. Two hundred and ninety-four implants supported 156 screw-retained zirconia prostheses consisting of a total of 441 units (including pontics and cantilevers). This resulted in a mean of 3.5 zirconia units per patient. Table 1 gives an overview. The FDPs were located mostly in the posterior maxilla (45%), followed by the anterior maxilla (19%), the posterior mandible (30%), and the anterior mandible (6%).

During the reported observation time, nine complete failures resulting in a need for refabrication occurred, meaning that 94.2% of SCs and FDPs remained functional without a need for refabrication. Reasons for failures included four fractures of the framework (1 SC, 3 FPDs) and massive chipping of the veneering material (3 SCs, 2 FPDs). One patient experienced two failures: one fracture of the framework and one instance of major chipping. Table 2 gives an overview of the failures and minor technical complications requiring maintenance service.

One fracture of a framework occurred in an elderly woman in the course of trauma (falling and hitting her

TABLE 1 Overview of Zirconia-Based SCs and FDPs

Implants and Prostheses		Total	Upper Jaw/ Lower Jaw
Implants and restorations	Implants	294	186/108
	Total restorations	159	100/59
	Total units	462	291/171
Type of restoration	SC	70	52/18
	FDP, 3 units	60	25/35
	FDP, 4–12 units	29*	23/6

*Including 11 full-arch maxillary FDPs of 12 units.

TABLE 2 Technical Complications and Failures

Event	1st Year	2nd Year	3rd Year	4th Year	5th Year and After	Total
Chipping/polishing	1*	0	2	1	1	5
Chipping/remake	3	0	0	1†	1	5
Fracture	1†	0	0	2	1*	4
Screw loosening	2	2	1	1	0	6
Implant loss	1	1	0	0	0	2

*Minor chipping and polishing; in the fifth year, major chipping and a fracture were detected.
†Fracture and refabrication; in the fourth year, major chipping was detected in a different location.

face). Another large fracture in the location of the central incisor was identified in a patient who had received two six-unit FDPs in the edentulous maxilla (Figure 4). Extensive chipping within the veneering material of several SCs in one patient occurred in the first year. This problem was probably caused by an insufficient anatomical framework design and inadequate veneering technique. Extensive chipping of the veneering material was identified in a bruxing patient with a maxillary 12-unit FDP. The chipping mode was fracture from the core material. In one case, small but clearly visible incisal chipping of the veneering ceramics of a short mandibular FDP was observed. This patient exhibited insufficient lateral occlusal guidance. Table 3 shows the life table analysis with the time intervals and CSRs. Figure 5 depicts the probability of failures and complications.

Two patients lost one implant each, but their zirconia prostheses (1 FDP, 1 SC) were not affected by technical problems.

DISCUSSION

In an early publication from the same clinical setting, preliminary results on the use of zirconia-based prostheses fitting on teeth and implants were presented.[20] Based on these favorable treatment outcomes, the indication for FDPs supported by implants was continuously extended with a focus on direct screw-retention. The strength of the present exploratory study on zirconia-based prostheses with screw-retention is that it reports on relatively large numbers of patients, SCs, and FDPs. Forty-one prostheses comprising 113 units survived for an observation time of more than 5 years. The present study reflects, to a certain degree, the initial and ongoing experience with screw-retained FDPs and with CAM fabrication of zirconia prostheses by means of the Procera technology. This technology had the capacity to produce frameworks of large dimensions and with direct screw-retention at an early stage. A comparison with PFM prostheses was not performed, as this would have limited the number of zirconia-based FDPs that could be examined in this case series.

Figure 4 Six-unit FPD, fracture of framework.

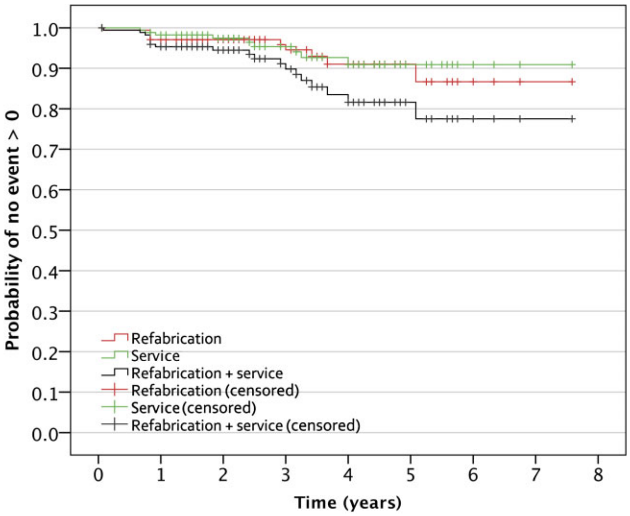

Figure 5 Kaplan-Meier curve. Red, probability of technical failure (refabrication); green, probability of technical complication (service); black, probability of all events (refabrication + service).

TABLE 3 Life Table Analysis

Interval (years)	Prostheses at Risk	Failure	Survival Interval	Percentage Surviving	Cumulative Survival Rate (%)
≤1	159	4	155	97.5	97.5
≤2	155	0	155	100	97.5
≤3	136	0	136	100	97.5
≤4	92	3	89	96.7	94.3
≤5	51	2	49	96.1	90.6
>5	41	0	41	100	90.6

The primary outcome of the present study was survival of the zirconia-based prostheses as represented by the CSR. The CSR after 5 years was 90.6%. The survival is considered satisfactory, taking into account that a new technology was used and the dentists and technicians experienced a learning curve. Some interpretations and explanations with regard to the complete failures were tentatively made. The CSR dropped significantly in the first year due to extensive chipping of one specific veneering material. Its use was then immediately stopped, and today the material is no longer on the market. Evaluation of the present data and CSR in comparison with results from clinical studies is not possible. Only minor information on a few screw-retained SCs is available, and data on FDPs are absent from the literature. In a narrative review, the concept of screw-retention and full-arch prostheses was clinically described.[23]

Concerns regarding the risk of fractures of zirconia frameworks or veneering materials exist, and a systematic review of 17 clinical studies analyzed these technical complications.[17] The authors concluded that fractures only occurred with soft-milled zirconia, but they identified chipping of the veneering as an ongoing problem. Two studies reported that frameworks of FDPs cemented on titanium or zirconia abutments did not exhibit any failures during an observation period of 3 to 5 years.[24,25] Crack propagation and fractures in the core and veneering material, however, are mentioned as risk factors of zirconia-based prostheses.[19,26] Currently, modifications of the core material preparation to hinder fractures are under investigation.[27]

In the present study, specific circumstances – like trauma as experienced by one elderly woman or bruxing habits – could explain the fracture events. With regard to the 6-unit FDP, the fracture in the incisor area appears to have originated from excessively close contact with the adjacent 6-unit FDP after screw tightening. Today, meticulous attention is paid to the proximal contact surfaces of adjacent zirconia-based FDPs. Furthermore, it appears that fitting ceramic prostheses on osseointegrated implants results in a hard and stiff prosthetic complex. One could speculate that this together with screw-retention might favor technical problems more than zirconia-based prostheses fitting on teeth or cement-retained on implants. Conversely, one study claims that the solid implant support of zirconia-based prostheses decreases stress and strain levels under occlusal load.[6] The concept of direct screw-retention at the implant level without the interposition of an abutment is a straightforward technology that may reduce inaccuracy in the laboratory procedures. Through careful planning with a favorable implant axis and regular implant distribution, the prosthesis design can be optimized, which should further favor accuracy and precision. By means of electron microscope measurements, one laboratory study compared screw-retained WAX- and CAD/CAM-fabricated zirconia frameworks of 10 units with the Procera system. The frameworks fitting on six maxillary NobelReplace implants were designed based on a real patient. The results gave evidence of high precision of fit for these large zirconia frameworks. All measurements exhibited gaps with an average of about 30 μm.[28] Similar results were documented for full-arch zirconia bars fabricated with a CAD/CAM system from a specialized milling center.[29] The present clinical study recorded 11 full-arch screw-retained FDPs that did not exhibit any framework fractures. Similar results on full-arch FDPs have been published just recently.[30]

The connection between implant and superstructure is a topic of ongoing dispute, and the biological and mechanical implant-abutment/implant-prosthesis connection is being investigated clinically and in laboratory studies.[31–33] As no abutments were used in the present study, the contact zone between zirconia framework and implant shoulder had a flat-to-flat design. Opening of the microgap between implant and superstructure under functional load is regarded as a biological problem, resulting in a quick internal bacterial colonization of the implant through the pumping effect. Therefore, a tight internal connection is often recommended, as it may hinder bacterial leakage and contributes to crestal bone stability by means of platform switching.[34–36] But there is also a mechanical aspect of the inner, conical connection.[37] From a mechanical point of view, the internal connection is ostensibly designed in order to face external forces and to protect the fastening screw, but this benefit was not confirmed in a recent laboratory study. A disadvantage of the inner connection without the shoulder support is the fact that there is no defined vertical stop obtained. Moreover, the material properties of zirconia may not be appropriate for internal connection. One laboratory study on internal connection identified massive fractures of the zirconia abutments in the inner conical part of the implant.[38] Thus, the flat-to-flat design with screw-retention may contribute to high stability and prevent fractures. Only one large screw is used. In the present study, screw loosening was a rare, insignificant event, and no screw fractures occurred during the entire observation period.

A more frequently mentioned risk of failure of zirconia-based FDPs, whether tooth- or implant-supported, is chipping of the veneering material.[39–41] By means of microscopic techniques, the type of veneering surface loss, whether chipping within the layered material or complete loosening from the core material, can be described.[26,39,42] Sometimes this distinction is difficult to make clinically if only a small area is involved, and therefore this technical complication is different from chipping in PFM prostheses, where the dark shine of the metal becomes visible. Thus, some patients may not be aware of minor chipping as long as crown shape and color do not change. Altogether, from the present data it appears that the feldspathic veneering material itself was not the crucial aspect. Presently, from current research it cannot be judged if the connection between implant and superstructure has any related effect on the chipping mode. Chipping as identified in the present study was explained by insufficient occlusal equilibration, by insufficient framework morphology in the beginning stage of framework fabrication, and by the fact that the completely edentulous bruxing patient had received zirconia-based FDPs in both jaws. A new maxillary full-arch FDP was fabricated from titanium with acrylic veneering to solve the chipping problem. In terms of the veneering process, it was also concluded that the firing protocol has to be adapted to the specific physical properties of the zirconia material, with appropriate preheating and cooling time.[43]

Common standards in reporting complications and failures have long been missing, and this problem has recently been addressed.[44] When technical failures and minor complications necessitating maintenance service in implant-supported zirconia prostheses are investigated, variables related to the fixation mode have to be considered. This aspect may affect conclusions on clinical outcomes.

CONCLUSIONS

Within the limitations of this retrospective study, it can be concluded that screw-retention is a feasible alternative for the retention of zirconia-based prostheses supported by implants. The risk of fractures and chipping exists within a limited frame.

ACKNOWLEDGMENT

The contribution of dental technician Remzi Kolgeci (Labor Bubenberg, Bern, Switzerland) is gratefully acknowledged.

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