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CLINICAL RESEARCH

Rehabilitation of edentulous jaws with zirconia complete-arch fixed implant-supported prostheses: An up to 4-year retrospective clinical study

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ABSTRACT

Statement of problem. Limited data are available on the clinical outcomes of patients with edentulism treated with zirconia complete-arch fixed implant-supported prostheses (CAFIPs).

Purpose. The primary purpose of this retrospective clinical study was to study the failure rate of dental implants as well as the fracture rate of zirconia CAFIPs. The secondary purpose was to study the survival outcomes of patients with edentulism treated with zirconia CAFIPs as well as the rate of technical complications.

Material and methods. This retrospective clinical study from private practice included 128 patients rehabilitated between January 1, 2013, and December 31, 2016, with 1072 implants supporting 191 zirconia CAFIPs for single-jaw as well as double-jaw rehabilitations. All zirconia prostheses were of 1-piece design and were veneered with feldspathic porcelain only at the gingival region and therefore considered as predominantly monolithic. Additionally, all prostheses were bonded to implant manufacturer's titanium cylinders that provided an intimate contact with the implants. The primary outcome measures were implant failure rate and prosthesis fracture rate. The secondary outcome measures were prosthodontic treatment survival rate and the incidence of technical complications with respect to monolithic zirconia CAFIPs. Cumulative survival rate (CSR) for implants and prostheses was calculated after a life-table survival analysis.

Results. Of the analyzed samples over a 4-year period, at least 288 implants and 49 prostheses had a minimum of 4 years of follow-up. A total of 18 implant failures were noted (13 in maxilla, 5 in mandible), yielding a CSR of 97.6% for implants. One fracture of the zirconia prosthesis was recorded, yielding a CSR of 99.4% for the prostheses over the 4-year period. Another 3 prostheses required remaking because the supporting implants failed, and 1 prosthesis was remade because the lack of passive fit resulted in a CSR of 96.8% for the prosthodontic treatment itself. During the 4-year period, 1 zirconia prosthesis had a technical complication related to the debonding of titanium cylinders, and 2 prostheses had fractured screws, which were resolved successfully. No zirconia prostheses had chipping of the veneered gingival porcelain.

Conclusions. Findings from this retrospective clinical study from private practice showed that prosthodontic treatment of edentulous patients with a 1-piece, complete-arch fixed implant-supported zirconia prosthesis with veneered porcelain restricted to the gingival region had high survival rates for implants and prostheses. Minimal technical complications related to this type of treatment for edentulous jaws and no chipping of the veneered gingival porcelain were encountered. (J Prosthet Dent 2018;120:204-9)

A variety of prosthodontic designs and biomaterials have been described for complete-arch fixed implant-supported prostheses (CAFIPs) (also known as fixed complete dentures) for the rehabilitation of patients with edentulism.[1] CAFIPs can be differentiated using 4 main parameters: mode of retention (screw-retained, cement-retained, or a combination when a single milled bar has separate crowns cemented over it); framework design (1-

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Clinical Implications

Because of their excellent survival rates and minimal technical complications, complete-arch fixed implant-supported prostheses made of zirconia offer a favorable treatment option for the rehabilitation of patients with edentulism.

piece, segmented, or a combination); prosthetic material blend (metal-acrylic resin, metal-composite resin, metal-ceramic, monolithic zirconia, or zirconia-ceramic); and use of prosthetic gingiva (denture base acrylic resin, gingival composite resin, gingival porcelain, gingival staining, or none).[1] All designs have certain advantages and disadvantages related to esthetics, strength, simplicity, method of fabrication, complications, and cost.

Zirconia is an emerging material for CAFIPs and has been reported to have multiple advantages for the clinician and patient, including good dental and gingival esthetics, better strength, better durability and wear characteristics, better biocompatibility compared with metal alloys, reduced plaque accumulation, and favorable soft-tissue response.[2] In addition, the mandated use of computer-aided design and computer-aided manufacturing (CAD-CAM) for zirconia has led to additional advantages, including better fit of the prosthesis because of digital technology for fabrication, reduced laboratory cost because of digital technology for fabrication, availability of a permanent digital file for future reproduction, and the opportunity for fabrication of a prototype or replica prosthesis in acrylic resin to be used for patient approval, adjustments, and contingencies. However, the disadvantages related to the use of this material include the inability to repair framework fractures, low tolerance of minor inaccuracies in the impression, difficulty in adjusting and polishing, and limited scientific data on clinical outcomes.[2]

The traditional monochromatic zirconia used in dentistry is yttria-stabilized tetragonal zirconia polycrystal (Y-TZP), which has a high fracture toughness ranging between 5 and 10 MPa·m[1,2] and flexural strength ranging between 900 and 1400 MPa.[3,4] These physical properties are the highest of all dental ceramics presently available.[3] Zirconia has been used in dentistry for over 15 years for varying indications, with a primary focus on replacing metal to improve esthetics.[3] However, the primary clinical complication related to the use of zirconia for fixed dental prostheses is the high rate of veneered porcelain fracture, ranging between 15% and 54%.[5,6] Protocols to eliminate or minimize chipping of veneered porcelain include digital cut-back, veneering only at the gingival region or non–load-bearing region, and the adoption of slower heating and cooling rates during porcelain firing.[3,7] Low-temperature degradation is suggested as a concern with zirconia and has been demonstrated in in vitro studies,[8,9] but the clinical evidence for failure caused by degradation of zirconia is lacking, and the fracture rate of zirconia frameworks has been reported to be less than 1%.[2,6,10,11] The use of monolithic zirconia or with minimally veneered porcelain is now popular to reduce technical complications, and dental laboratories even offer warranties to indemnify against any prosthesis fracture.[11]

A recent systematic review[2] on zirconia CAFIPs identified 12 studies reporting on 285 zirconia CAFIPs and showed a failure rate of 1.4% from zirconia framework fractures in the short term. However, this review also reported that zirconia CAFIPs with veneered porcelain have a 14.7% rate of complications related to the chipping of veneered porcelain. To mitigate this issue, the authors recommended the use of high-quality zirconia that is veneered only at the gingiva or the use of monolithic zirconia with only gingival characterization. The authors concluded that future long-term clinical studies on this recommended design of zirconia CAFIPs are needed.[2] Another recent systematic review on this topic also recommended the need for clinical studies on zirconia CAFIPs.[10]

Therefore, the purpose of this retrospective clinical study was to evaluate the survival outcomes of titanium dental implants as well as the survival of zirconia complete-arch fixed implant-supported prostheses veneered only in the gingival region.

MATERIAL AND METHODS

This retrospective clinical study included 128 consecutive patients treated in private practice between January 1, 2013, and December 31, 2016, with 1072 titanium dental implants supporting 191 zirconia CAFIPs. All dental implants were internal hexagon connection implants (Tapered Internal; Biohorizons) of varying implant diameters (3.8 mm, 4.6 mm, and 5.8 mm) and included axially aligned as well as tilted implants, depending upon the clinical situation. All patients were treated under standardized surgical and prosthodontic protocols to allow ostectomy for the creation of at least 11 to 12 mm of prosthetic space above the soft tissues for adequate strength of the zirconia[11] (Fig. 1). This dimension also allowed all prostheses to have veneered porcelain at the gingival region to improve esthetics.[1] With the exception of 5 jaws in which computer guided surgery was used, all implants were placed by a conventional free-hand surgery technique after systematic treatment planning for prosthetic space and implant positions. Cone beam volumetric imaging (CBVI) was used for all treatments. Typically, 6 implants were used to support a maxillary prosthesis, and 5 implants were used to support a

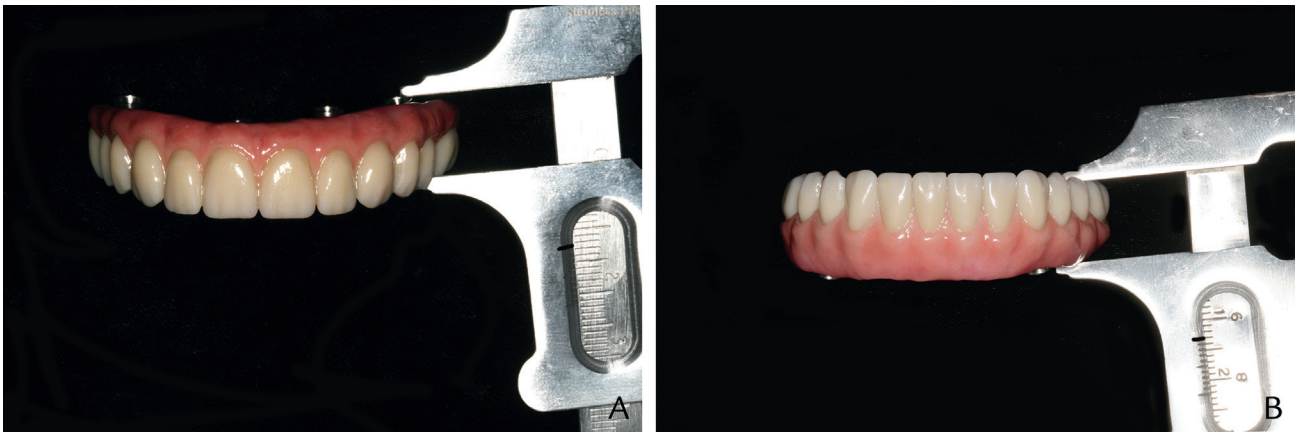

Figure 1. Monolithic zirconia fixed prostheses with veneered porcelain restricted to gingival region. A, Maxillary. Thickness measured 12 mm. B, Mandibular. Thickness measured 13 mm.



Figure 2. Occlusal view of mandibular zirconia prosthesis showing prosthetic design.



Figure 3. Profile view of maxillary zirconia prosthesis showing prosthetic design and favorable tissue contour for better oral hygiene. Also note titanium cylinders bonded to provide metal-to-metal interface over abutments.

mandibular prosthesis. The loading of the implants was immediate or delayed, depending upon the clinical situation and patient preference. If the loading was delayed, the patient was provided with a removable complete denture. A minimum healing period of 3 months was allowed before fabricating the definitive prostheses.

The CAFIPs were all fabricated with the same brand of zirconia (Prettau Zirconia; ZirkonZahn) by using the standardized fabrication protocols recommended by the manufacturer. All zirconia prostheses were of 1-piece design, screw-retained, predominantly monolithic, and with veneered porcelain restricted to the gingival region (Fig. 2). No prostheses were dentition-only replacements, indicating that sufficient prosthetic space existed for all prostheses for gingival porcelain.[2] The zirconia prostheses were fabricated for implant-level and abutment-level prosthetic platforms or a combination of the two. All prostheses had an indirect zirconia interface (bonded to implant manufacturer's prefabricated titanium cylinders), and all prostheses had a distal cantilever of varying lengths but not exceeding 12 mm. The passive fit of each prosthesis was confirmed by tactile, visual, radiographic, and 1-screw Sheffield tests.[12]

All prostheses were fabricated on definitive casts produced conventionally using a splinted impression coping technique.[13] The tissue surface of all prostheses was rounded and smooth to produce favorable contours and facilitate the patient's oral hygiene (Fig. 3). The tissue surface was evaluated clinically with slight tissue pressure that produced blanching that resumed normal coloration within a few minutes of insertion for the majority of prostheses; a small number of prostheses had a space above the soft tissues for better access for oral hygiene. All prostheses were tightened to the manufacturer's recommendations (15 Ncm for prosthetic screws and 30 Ncm for abutment screws) by using the appropriate screw depending upon whether the prosthesis was fabricated at implant level, abutment level, or a combination of the two.

Table 1. Four-year life table survival analysis of implants supporting zirconia complete-arch fixed implant-supported prostheses

Time Interval (y)	Implants in Interval (n)	Failures in Interval (n)	Interval Survival Rate (%)	Cumulative Survival Rate (%)
0-1	1072	12	98.8	98.8
1-2	716	3	99.4	98.3
2-3	536	3	99.3	97.6
3-4	288	0	100	97.6

Mutually protected, group function, or partial group function articulation was chosen for all prostheses. The same protocol and prosthetic design was followed for single-jaw or double-jaw rehabilitations. After treatment, all patients were followed up every 3 to 4 months for routine professional oral hygiene maintenance visits and for any biological or mechanical complications, and the findings were recorded.

In this study, implant failure was defined as the absence or loss of an implant requiring replacement for any reason. Prosthesis failure was defined as fracture of any part of the zirconia prosthesis that required remaking the prosthesis. Prosthodontic treatment failure (patient-level failure) was defined as the need to remake a prosthesis for any reason other than prosthesis fracture. Technical complication was defined as an unanticipated event that affected any or all of the zirconia prosthesis and required a material-specific dental laboratory intervention, but without replacement with a new zirconia prosthesis. The zirconia prosthesis itself had to be intact and in one piece. Based on these definitions, all failures and technical complications were recorded for 128 consecutively treated patients over a 4-year period, and data were tabulated and analyzed using a life table survival analysis to calculate interval survival rate (ISR) and cumulative survival rate (CSR).

RESULTS

Of 1072 implants, 618 implants were placed in the maxilla and 454 implants were placed in the mandible. The majority of the implants (795) were 3.8 mm in diameter, followed by 4.6-mm implants (249) and 5.8-mm implants (28). A total of 18 implant failures were recorded (13 in the maxilla and 5 in the mandible). The majority of implant failures (12 of 18) were early failures occurring within the first-year interval of follow-up. The life table survival analysis showed a 4-year CSR of 97.6% (Table 1).

Of 191 zirconia CAFIPs, 102 prostheses were made in the maxilla, and 89 prostheses were made in the mandible. Sixty-one patients had single-jaw rehabilitations opposing either natural teeth, mixed or restored dentition, or removable prostheses (32%). A total of 65 patients were treated for double-jaw rehabilitations with 130 zirconia prostheses (68%).

Table 2. Four-year life table survival analysis of zirconia complete-arch fixed implant-supported prostheses

Time Interval (y)	Zirconia Prostheses in Interval, n	Fractures (Failures) in Interval (n)	Interval Survival Rate (%)	Cumulative Survival Rate (%)
0-1	191	1	99.4	99.4
1-2	127	0	100	99.4
2-3	93	0	100	99.4
3-4	49	0	100	99.4

Table 3. Four-year life table survival analysis of prosthodontic treatment with zirconia complete-arch fixed implant-supported prostheses

Time Interval (y)	Zirconia Prostheses in Interval (n)	Remakes (Failures) in Interval (n)	Interval Survival Rate (%)	Cumulative Survival Rate (%)
0-1	191	2	98.9	98.9
1-2	127	2	97.8	96.8
2-3	93	0	100	96.8
3-4	49	0	100	96.8

Seventy-four prostheses (38.7%) were inserted after an immediately loaded protocol was followed, and 119 prostheses (62.3%) were inserted after a delayed loading protocol. Overall, there was a fracture of 1 zirconia prosthesis due to adjacent implants being too close to each other, resulting in a thin zirconia layer. This resulted in a 4-year CSR of 99.4% (Table 2). Remaking the prosthesis and excluding 1 of the implants successfully resolved this fracture.

A total of 3 zirconia CAFIPs needed to be remade because of implant failures, where strategic implants that supported the prosthesis had to be replaced in a slightly different site in the arch than the failed implants. Two of these were in the same patient with a double-jaw rehabilitation. One more zirconia CAFIP was remade because of inadequate passive fit, resulting in a 4-year CSR for prosthodontic treatment of 96.8% (Table 3). With respect to technical complications, the titanium cylinders in 1 zirconia prosthesis debonded, and screws fractured in 2 prostheses. These complications were all resolved successfully, without re-occurrence. No chipping of the veneered gingival porcelain or other technical complication was observed over the 4-year study period.

DISCUSSION

The objective of this retrospective study was to report on the failure rate of dental implants as well as the fracture rate of zirconia CAFIPs. An additional objective was to study the survival outcomes of prosthodontic treatment of patients with edentulism with zirconia CAFIPs as well as the rate of technical complications. To the authors' knowledge, the present clinical study has the largest sample size and follow-up period. Zirconia is a relatively

new material, and its application to CAFIPs is relatively novel, with few studies reporting on its use.[2] Therefore, building scientific evidence is essential to the understanding of the performance and promise of this material in the treatment of patients with edentulism.

The majority of implant failures documented in this study occurred within the first year and were considered early failures. The implant cumulative failure rate of 2.4% is similar or slightly better than the reported rate.[14,15] Some of the implant failures occurred after the definitive zirconia CAFIPs had been inserted, and this resulted in the remake of 4 prostheses after new implants had been placed. Despite the low number of implant failures, maxillary implant failure (13 of 18) was almost 3 times higher than mandibular failure (5 of 18). This difference has also been noted by others.[14,15] This finding warrants careful consideration during treatment planning of the edentulous maxilla, and placement of additional "reserve implants" in strategic locations should be considered to avoid remaking the maxillary prostheses.

A limitation of this study was that marginal bone loss data were not recorded because the authors did not have a standardized mechanism for periapical radiographs. Nevertheless, none of the implants had gross marginal bone loss, which the authors defined as exceeding 30% of the implant length observed during the follow-up visits.

Comparing the results of this study with those on conventional metal-resin CAFIPs indicates a significantly reduced number of technical complications related to the high rate of fracture of acrylic resin and denture teeth, debonding of denture teeth, wear of the acrylic resin, and the need for repair, retread, and replacement.[16-20] These complications have been reported to be significantly higher in double-jaw metal-resin CAFIPs.[9] Comparing the results of this study with those of other clinical studies reporting on monolithic zirconia or minimally veneered zirconia CAFIPs, we find similar results, although the number of prostheses in other studies was smaller than in the present study.[2] Comparing the results of this study with other clinical studies on conventional veneered zirconia CAFIP, we find a significantly reduced number of technical complications; previous studies have reported rates of chipping and/or fracture of veneered porcelain as high as 46.5%.[21] In this study, no chipping of the veneered gingival porcelain was found, primarily because the gingival porcelain was restricted to a non–load-bearing area and was well-supported by the digital cut-back process. In this study, no prostheses had any veneered porcelain on the dentition itself. However, all prostheses were characterized (using manufacturer's acidic stains) to make the teeth look natural and esthetic, which satisfied the patients' esthetic needs.

The high survival rate of zirconia CAFIPs reported may be due to the quality of the zirconia used, careful adherence to laboratory protocols, creation of 11- to 12-mm prosthetic space above the soft-tissue level to provide sufficient strength for the zirconia, avoidance of excessive distal cantilevers, use of the implant manufacturer's original titanium cylinders bonded to zirconia to provide a metal-to-metal interface over the implants or abutments, and provision of a milled acrylic resin prototype prosthesis to allow adjustment of occlusion and esthetics before fabricating the zirconia prosthesis.[11] The authors did not identify any difference in prosthesis fracture or technical complications in a single-jaw versus double-jaw rehabilitation with zirconia CAFIPs, or between prostheses and without a distal cantilever. Future studies with large sample sizes and long-term follow-up are needed to validate the findings of this study.

CONCLUSIONS

Within the limitations of this short-term retrospective clinical study from private practice, the following conclusions were drawn:

1. The 4-year CSR of implants supporting complete-arch fixed implant-supported zirconia prostheses was 97.6%, attributable to 18 implant failures.
2. A fracture of 1 zirconia prosthesis occurred due to adjacent implants being too close to each other, resulting in a 4-year CSR of 99.4%.
3. Three prostheses required remaking because of the failure of supporting implants, and 1 prosthesis was remade because of lack of passive fit, resulting in a 4-year of CSR of 96.8% for the prosthodontic treatment.
4. Debonding of titanium cylinders occurred in 1 zirconia prosthesis, and 2 prostheses had fractured screws, which were all resolved successfully. No zirconia prostheses had chipping of the veneered gingival porcelain.

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