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Retrievable Metal Ceramic Implant-Supported Fixed Prostheses with Milled Titanium Frameworks and All-Ceramic Crowns: Retrospective Clinical Study with up to 10 Years of Follow-Up

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Abstract

Purpose: The purpose of this study was to report on the outcome of metal ceramic implant-supported fixed prostheses with milled titanium frameworks and all-ceramic crowns.

Materials and Methods: The clinical study included 108 patients (67 women, 41 men), mean age of 58.6 years (range: 34–82), followed between 9 months and 10 years (post occlusal loading). The mean follow-up time for all patients in the study was 5 years. A total of 125 prostheses were fabricated. The data were divided into 2 groups. Development group (DG): 52 patients with 66 prostheses (28 maxillary, 38 mandibular) fabricated with individual Procera crowns (Alumina copings, Nobel Biocare AB) and Allceram ceramics (Ducera Dental GmbH) cemented onto a CAD/CAM fabricated Ti framework (Nobel Biocare AB) with pink ceramic (Duceram, Ducera Dental GmbH) that replicated the missing gingival tissues. Routine group (RG): 56 patients with 59 prostheses (49 maxillary, 10 mandibular) fabricated with individual Procera crowns (Zirconia copings and Nobel Rondo Zirconia Ceramic; Nobel Biocare AB) cemented onto a CAD/CAM fabricated Ti framework (Nobel Biocare AB) with pink acrylic resin (PallaXpress Ultra, Heraeus Kulzer GmbH) that replicated the missing gingival tissues. Primary outcome measures were prosthetic survival and mechanical complications. Secondary outcome measures were biological complications testing the retrievability characteristic of the prosthesis. Survival estimates were calculated on the patient level with the Kaplan-Meier product limit estimator (95% confidence intervals [CI]). Data were analyzed with descriptive and inferential analyses.

Results: The cumulative survival rates for the implant-supported fixed prostheses were 92.4% for the DG at 10 years and 100% for the RG at 5 years (overall 96%) (Kaplan-Meier). Mechanical complications occurred in 44 patients (DG: 29 patients, 36 prostheses; RG: 15 patients, 16 prostheses); the large majority were crown fractures, occurring in 48 patients (DG: 33 patients, 36 prostheses; RG: 15 patients, 16 prostheses). In the DG, univariate analysis of logistic regression disclosed the presence of a metal ceramic implant-supported fixed prosthesis opposing dentition as a risk factor for crown fracture (OR = 1.97). Biological complications occurred in 33 patients (DG: 18 patients; RG: 15 patients), the majority being peri-implant pathologies in 19 patients (DG: 9 patients, RG: 10 patients). All situations were resolved except one in the DG that led to fixture and prosthesis loss.

Conclusions: The results of this study indicated that, within the limitations of this study, the CAD/CAM protocol is acceptable for definitive prosthetic rehabilitation. This protocol provided these patients with a good prognosis on a middle- to long-term basis (5 years).

Implant-supported fixed prostheses have increasingly been the first-choice treatment for the rehabilitation of edentulous areas.[1-3] Replacement of complete dentures with fixed implant-retained prostheses has achieved predictable high cumulative survival rates.[4] It is the authors' opinion that additional research should focus on types of frameworks, fabrication techniques, and their predictability. This should coincide with the development of new prosthetic solutions for treating edentulous patients with improved quality of materials, esthetics, biomechanics, facilitation of hygienic maintenance, retrievability, and long-term prognoses for patients and prostheses.

Economically, it has also proved to be important for new technologies to be cost effective, as well as accurate and predictable. Goals related to developing and using new technologies should include using state of the art dental technology, reliable materials, and solutions to problems previously encountered with preexisting technology. Implant frameworks should be biocompatible, have excellent physical properties in terms of strength, fit accurately to implants and abutments,[5] and be compatible with esthetic veneering materials such as ceramic and acrylic resins. A passive fit of implant-supported prostheses is considered a prerequisite for the prevention of mechanical complications,[6] and therefore prosthetic success. Two main reasons emerge for complications in the prosthesis framework or veneer: lack of passive fit between the restoration and the abutment and destructive occlusal contacts.[7]

Because implants lack the stress release associated with a periodontal ligament, impact loading to restorative materials and the crestal bone remains potentially more damaging with implant-supported restorations.[8] It is therefore believed that dental implants may be more prone to occlusal overloading, which is often regarded as one of the potential causes of peri-implant bone loss and failure of the implant/implant prosthesis.[9] Overloading factors that may negatively influence implant longevity include large cantilevers, parafunctions, improper occlusal designs, and premature contacts.[9] In this field and amongst other factors, porcelain fractures[10] and marginal bone resorption[11] seem to be significantly associated with opposing implant-supported metal ceramic restorations.

Two basic methods are currently used in the fabrication of implant frameworks: the conventional lost wax/casting technique[12] and CAD/CAM milling procedures where frameworks are milled from solid blanks of titanium, titanium alloy, or ceramic materials such as zirconia.[13] The benefits of the lost wax/casting technique include the ability to create optimal esthetics due to the proven technology associated with porcelain fused to metal,[14] high biocompatibility with gold alloys,[15,16] and the ability of most commercial dental laboratories to fabricate implant frameworks with this proven technology. The limitations of the lost wax/casting technique include the precision of fit, described by numerous researchers.[17-19] It is not uncommon to have to section cast metal frameworks to obtain precise, passive fits between frameworks and implants. The sections must then be connected via welding or soldering.[20-22] The rigid connectors are known to be the weakest parts of these castings.

Several advantages are associated with CAD/CAM systems (Ti alloy with ceramic applied to it):[13,23,24] biocompatibility,[25] highly precise fit,[13] the possibility of extended cantilever lengths (due to characteristics of Ti/zirconia, which can be shaped only by CAD/CAM systems),[26] the lack of rigid connectors such as solder or welded joints within the CAD/CAM framework, and that it is machine manufactured,[25] thus less susceptible to human error. A potential limitation associated with CAD/CAM technologies is that ceramics do not bond well to Ti or Ti alloy.[27] However, both technologies have limitations. A potential disadvantage might be the physical properties associated with the metal castings including limited cantilever lengths and increased expense due to the recent increases in prices for noble metals. Both technologies are limited when deficiencies are noted regarding insufficient metal to support the prosthesis.

For both technologies the management of ceramics is also a concern. This may be due to technique sensitivity.[28]

Dealing with ceramic fractures is another disadvantage present in both technologies. Fractures may be repaired by adding additional ceramic and refiring the prosthesis; however, this may increase the probability of damaging the non-rigid connectors (in the lost wax/casting technique) and potentially damaging the ceramics due to too many baking cycles (in both technologies).[29] Difficulty in masking screw access openings is another disadvantage present in both technologies.

Evidence supports the use of full ceramics on implant prostheses.[30,31] The constant evolution of ceramics includes several advantages including excellent esthetics,[31] high fracture resistance, maintenance of vertical dimension, increased longevity,[32] better hygiene,[33] better stain resistance,[34] and greater ability to customize.[35]

The theoretical rationale for developing implant-supported fixed prostheses with CAD/CAM fabricated frameworks (Procera) and individualized crowns incorporates the advantages of both technologies while minimizing the disadvantages. By using a framework produced by one specific CAD/CAM system (Procera), the authors sought to use the following advantages: high precision of fit,[36] longer cantilever lengths, use of fewer implants to support the prostheses,[1] biocompatibility, elimination of rigid connectors, frameworks less susceptible to human error, and standardized fabrication procedures.

The authors designed the prostheses with individual Procera crowns to use the following advantages: high esthetics,[37-39] high capacity of repair (by individually cementing the crowns it is possible to repair without removing the whole structure). This allows the benefits of repairability (repairing without removing the whole structure) and cushion effect. Additionally, if any misjudgement is made in the vertical dimension or position of the teeth, it is easily solved by the double scan characteristic of the Procera system,[40] which offers a good prognosis in the medium and long term.[30,41]

Several reports, including a review focused on the prosthodontic survival outcome of these types of rehabilitation, report survival rates ranging between 87% and 92.1% with a follow-up between 5 years and 15 years.[42-47] This methodology was designed for patients in need of a rehabilitation solution for a full metal ceramic implant-supported fixed prosthesis using the advantages of different concepts and materials to ensure consistently high-quality prostheses. The purpose of this clinical study was to document the clinical and laboratory procedures to fabricate implant-supported standardized fixed metal ceramic prostheses. The null hypothesis was that there would

Table 1 Population and methods (development and routine groups)

Population and methods	Development group	Routine group
Number of patients	52	56
Gender distribution	23 women, 29 men	35 women, 21 men
Mean age (range)	59.5 years (38–81)	57.6 years (34–82)
Number of prostheses (distribution per arch)	66 (28 maxillary, 38 mandibular)	59 (49 maxillary, 10 mandibular)
Type of titanium framework	Procera Titanium framework (Nobel Biocare AB)	
Technology	CAD/CAM	
Type of copings	Alumina copings (Nobel Biocare AB)	Zirconia copings (Nobel Biocare AB)
Type of ceramic used to fabricate the crowns	Allceram (Ducera Dental)	Nobel Rondo Zirconia Ceramic (Nobel Biocare AB)
Type of material replicating gingival tissues	Duceram (Ducera Dental)	PalaXpress Ultra (Heraeus Kulzer GmbH)

be no differences in the survival and complication outcomes of the implant-supported treatments using the current protocol or other CAD/CAM technologies.

Materials and methods

This clinical study was performed in a private center (Malo Clinic), in Lisbon, Portugal, and included 108 completely edentulous patients (67 women, 41 men), with an average age of 58.6 years (range: 34–82), rehabilitated through implants in immediate function. Inclusion criterion was patients in need of definitive implant-supported fixed rehabilitations having successfully overcome the osseointegration period. Exclusion criteria were patients who did not overcome the osseointegration period and the presence of compromised implants that could affect the survival outcome at the time of the definitive prosthesis manufacture. Regarding systemic conditions, 17 patients had cardiovascular problems, four patients had thyroid problems, one patient had diabetes, and one patient was immune compromised. Eighty-five patients were healthy. A total of 634 implants (Branemark system, Nobel Speedy; Nobel Biocare AB, Göteborg, Sweden) were placed. Multi-unit straight and 30° angulated abutments (Nobel Biocare) were used in the rehabilitations. Six months after the surgical procedure, the patients were rehabilitated with 125 definitive dental prostheses (77 maxillary, 48 mandibular). The same team performed the surgical and prosthodontic treatments. The first prosthesis was placed in January 2000; the last prosthesis was placed in February 2007. The patients were followed between 9 months and 10 years, with a mean follow-up of 5 years.

Patients were treated at one rehabilitation center (Malo Clinic); all patients were in need of definitive full-arch dental prostheses. The study was approved by an independent ethical committee, and written informed consent to participate in this study was obtained for all patients. The cohort was divided into two groups, with a development group and a routine group. The development group consisted of 52 patients (23 women, 29 men), with an age range of 38 years to 81 years (mean: 59.5 years). Sixty-six prostheses (28 maxillary, 38 mandibular) were fabricated for the development group using the CAD/CAM protocol (Table 1), with a mean follow up of 78 months (range: 9 months to 127 months).

The routine group included 56 patients (35 women, 21 men), with an age range of 34 years to 82 years (mean: 57.6 years). Fifty-nine prostheses (49 maxillary, 10 mandibular) were fabricated, with a mean follow-up of 46 months (range: 12 months to 67 months; Table 1).

Regarding the laboratory protocol, prostheses in the development group had the following characteristics: 12 to 14 individual Procera crowns (Alumina copings, Nobel Biocare AB) with Allceram ceramics (Ducera Dental GmbH, Rosbach, Germany) cemented onto a Procera Titanium framework (Nobel Biocare AB) with pink ceramic (Duceram, Ducera Dental GmbH) replicating the missing gingival tissues. The criteria for doing 12 or 14 crowns, anterior–posterior spread, and number of implants per arch were based on the degree of jaw atrophy. A minimum of 12 crowns and a maximum of 14 crowns were placed. If the emergence position of the most posterior implant was on the second premolar, two cantilevers were included in the prosthesis. If the emergence position of the implant was located on the first molar, one cantilever was included, and if the emergence position of the implant was the second molar, no cantilevers were included. The mean number of implants per arch was five (range: 4 to 11 implants), with the following distribution: 81 prostheses supported by four implants; five prostheses supported by five implants; 16 prostheses supported by six implants; six prostheses supported by seven implants; 14 prostheses supported by eight implants; two prostheses supported by 10 implants; and one prosthesis supported by 11 implants.

Interocclusal space and vertical dimension were maintained if the patient presented with teeth prior to the rehabilitation process. If the patient presented with removable dentures, the vertical dimension was maintained, and the interocclusal space was maintained when possible.

In the routine group, the changes implemented were related to the materials used [alumina copings were replaced by zirconia copings with Nobel Rondo Zirconia Ceramic (Nobel Biocare AB), and pink acrylic resin (PalaXpress Ultra, Heraeus Kulzer GmbH, Hanau, Germany) was used instead of pink ceramic]. Regarding the protocol, no differences existed between the clinical procedures used on the patients in both groups. The authors designed the intaglio surfaces of the prostheses to improve the ease of oral hygiene procedures by the patients.

To avoid esthetic and/or functional compromises, screw access openings were positioned as palatal as possible on the occlusal surfaces of posterior teeth or on the false palatal interdental papilla of the anterior teeth, preventing a visible vestibular screw access opening that could compromise esthetics. In some situations, the angulation of some implants dictated the use of angulated abutments (17° or 30° multi-unit angulated

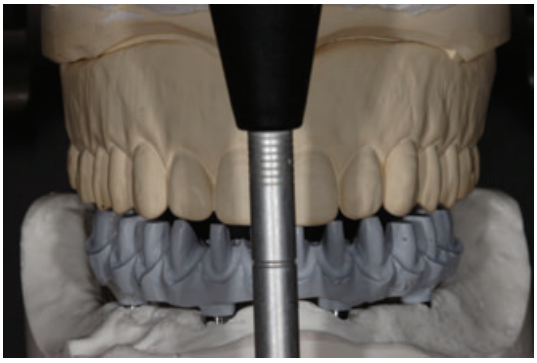

Figure 1 Production of the titanium framework. Acrylic duplicate prepared to be scanned.

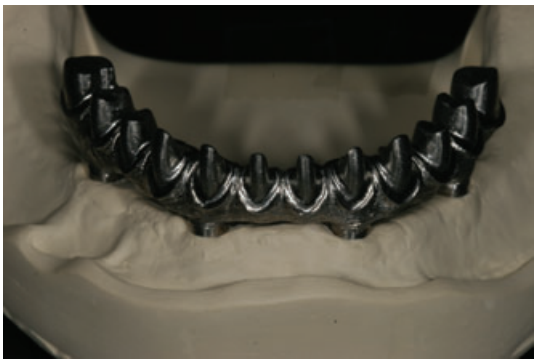

Figure 2 Titanium framework finished and polished.

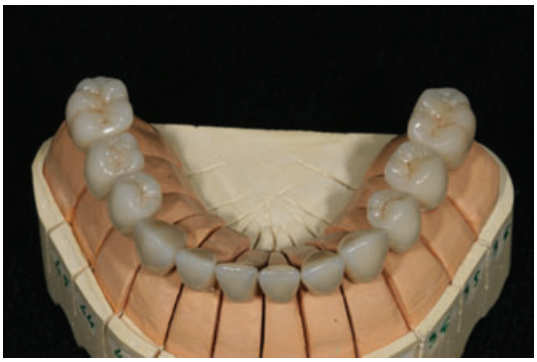

Figure 3 Procera crowns were manufactured according to the interim prosthesis and the prosthodontist's specifications.

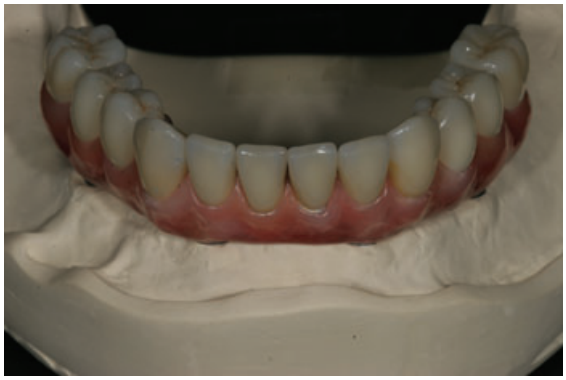

Figure 4 The crowns were cemented to the framework extraorally.

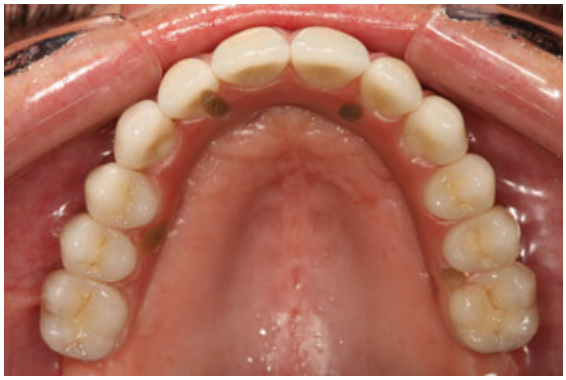

Figure 5 Occlusal view of the prosthesis.

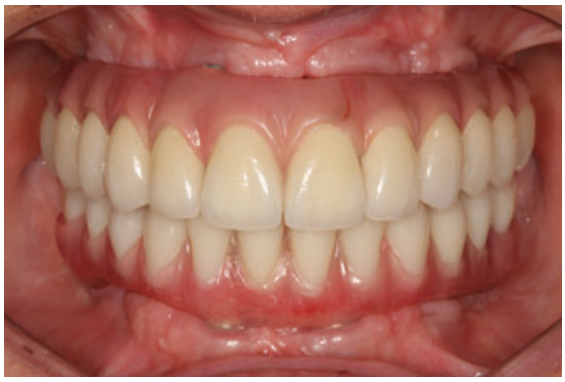

Figure 6 Intraoral view of the maxillary prosthesis in occlusion.

abutments, Nobel Biocare AB) to achieve a nonvisible screw access opening.

All definitive impressions were achieved in two steps. The first step was to splint together multi-unit impression copings (Nobel Biocare AB) or fixture-level impression copings (Nobel Biocare AB) with stainless-steel bars and a low contraction autopolymerizing acrylic resin (GC Pattern Resin, GC Co, Alsip, IL). Definitive impressions were made with custom, open trays and addition reaction silicone impression material (Light Body and Putty Soft, fast setting; Zhermack Co, Rovigo, Italy).

The dental laboratory used the tooth arrangement on the interim implant-supported fixed prostheses as a starting point to manufacture the definitive prostheses. First, an acrylic resin screw-retained pattern of the interim implant-supported fixed prosthesis was made on the master cast to plan the future Ti framework. This acrylic resin pattern was fabricated with individual crown preparations (12 to 14) to accommodate the corresponding individual ceramic crowns (Nobel Biocare AB; Fig 1). After the pattern was completed, the pattern was ready to be scanned and read by the Procera software (Nobel Biocare

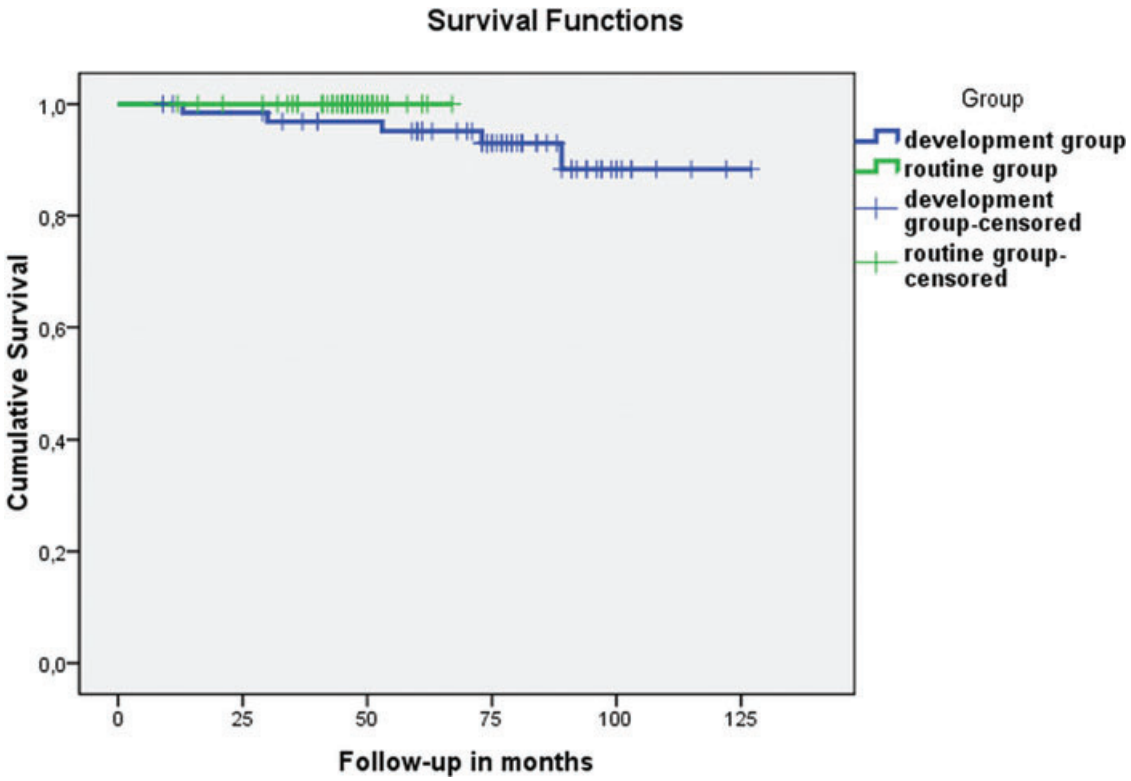

Figure 7 Prosthesis survival using Kaplan-Meier product limit estimator.

AB). The data were transferred digitally to a milling machine for fabrication of the Ti framework (Fig 2).

Once the Ti frameworks were milled, the ceramic copings were fabricated. Silicone impressions were made of the preparations within the frameworks. The copings were then milled.

The ceramic was applied individually to each coping (Allceram for the development group; Nobel Rondo Zirconia Ceramic for the routine group). Finally, after all the crowns were glazed, the implant-supported fixed prostheses were completed. The crowns were cemented to the preparations using a definitive cement (Fig 3), the screw access openings were opened, and the customized acrylic gingiva (Unifast TRAD, GC Co, Tokyo, Japan) was applied and polymerized around the crowns and in the inferior portion of the prosthesis (Fig 4).

For the routine group, all implant-supported fixed prostheses were placed without trial placements or any other type of extra visits apart from the final connection of the prosthesis (Fig 5). All prosthetic screws were given a final torque of 15 N/cm. The prosthetic screw access holes were sealed using cotton pellets and composite material (Fig 5), and the occlusion was evaluated respecting the following occlusion scheme: in the excursive movement, disclosure in anterior teeth; lateral movement of the mandible was a canine function with absolutely no prematurities; the excursion of canines and lower incisors was in a slope of less than 10° when possible. Due to the tendency of these patients to slightly modify the occlusion pattern, occlusion was checked according to these guidelines, especially in the first 6 months.

Canine guidance was based on lateral eccentric movements, incisive guidance on protrusive movements and balanced contacts in maximal intercuspation (Fig 6). The follow-up examinations were scheduled at the connection of the prosthesis and after 2 and 6 months, 1 year, and thereafter each year.

Complication parameters were assessed. *Mechanical complications*: fracture or loosening of mechanical and prosthetic components (using magnifying glasses and a probe to check for small chips or cracks), lack of passive fit (by placing the fixed partial denture [FPD] over the implants making sure there was no pressure on the soft tissue and using only one prosthetic screw attached to the implants. The verification was done with magnifying glasses at the FPD/abutment interface and using a probe or radiologically if the interface between prosthesis and abutment was not visible). *Biological complications*: soft tissue inflammation, fistula formation, pain or peri-implant pathology; *Esthetic complications*: esthetic complaints of the patient or dentist; *Functional complications*: phonetic complaints, masticatory complaints, and comfort complaints; *Oral hygiene complications*: low levels of oral hygiene. Descriptive statistics were used to analyze the outcome of complications in both groups.

The survival criteria implemented in this study were based on the functionality of the prosthesis. A prosthesis was considered a success if it remained in function and did not need to be substituted. The survival estimate was calculated on patient level through the Kaplan-Meyer product limit estimator with 95% confidence intervals (CI).

The association between the variables "presence or absence of metal ceramic implant-supported prosthesis as opposing dentition" and "crown perforation" (crowns with screw access openings versus crowns without screw access openings) and the outcome variable "incidence of fractured crowns" was evaluated by unconditional logistic regression to estimate odds ratios (ORs) and corresponding 95% CIs. The effect of each variable was assessed both in univariate (crude) analysis and after adjustment for the other variables of interest. The level of significance considered was 5%. The statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 19.0 (2009; SPSS Inc., Chicago, IL).

Results

Twelve patients were lost to follow-up during the completion of this study, representing 11% of the sample size. The overall survival rate of the implant-supported fixed prostheses was 96% at 10 years of follow-up (Kaplan-Meier). The overall survival estimate for the implant-supported fixed prostheses was 120.9 months 95% CI: 115.5 months to 126.3 months (maximum follow-up registered was 127 months).

The development group rendered a 92.4% survival rate at 10 years of follow-up (Kaplan-Meier). Five prostheses in this group were replaced by acrylic resin prostheses due to recurrent crown fractures. Mechanical complications occurred in 29 patients and 36 prostheses, ranging from crown fracture (between 1 and 91 months of follow-up; anterior crowns—12 prostheses; posterior crowns—15 prostheses; anterior and posterior crowns—six prostheses; in a total of 33 prostheses with crown fractures: 29 with complete fractures and four with chipped ceramics), abutment loosening (two in 29 prostheses), and chipping of the ceramic gingiva (three in 36 prostheses). In two patients, more than one incidence of mechanical complications occurred. From the 33 prostheses with crown fractures, 24 prostheses' opposing dentition was a metal ceramic implant-supported fixed prosthesis. Presence of a metal ceramic implant-supported fixed prosthesis as opposing dentition was found to be a risk factor for the incidence of mechanical complications in the development group in the logistic regression model both in univariate analysis (OR = 2.04) and after adjusting for "crown perforation" (OR = 1.97; Table 2). No further mechanical complications were registered in the development group.

The routine group rendered a 100% survival rate at 5 years of follow-up (Kaplan-Meier; Tables 3, 4; Fig 7). Mechanical complications occurred in 15 patients and 16 prostheses, consisting of crown fractures (between 4 months and 54 months of follow-up; anterior crowns—six prostheses; posterior crowns—four prostheses; anterior and posterior crowns—four patients; in a total of 14 prostheses with fractured crowns: 13 with complete fractures and one with chipped ceramics), abutment loosening (one patient), and abutment substitution (one patient).

No significant effects were revealed in the logistic regression analysis for the outcome "incidence of mechanical complications". No further mechanical complications occurred in the routine group.

For both groups, the ceramic fractures that implicated removing the crown were repaired immediately in the mouth by the dentist with a provisional crown, and later a ceramic crown was manufactured and cemented. The Procera software saves the files of previously scanned dies, making it possible to produce a new coping with the exact same characteristics. The implant-supported fixed prostheses were never removed from the mouth nor baked again during this process. The repairing process ended with the manufacture of a night-guard. The abutment loosening was solved by adjusting the patients' occlusion and manufacturing an occlusal night-guard.

The chipping of the ceramic gingiva in the development group (that created a gap on the affected prosthesis) was repaired by the clinician using a special pink-colored resin composite (Gradia Gum, GC Company, Tokyo, Japan). No further mechanical complications were registered during the follow-up of this study.

The incidence of biological complications registered in the development group occurred in 18 patients, including peri-implant pathology (nine patients), soft tissue inflammation (seven patients), and implant loss (two patients). The peri-implant pockets were solved through non-surgical therapy (removal of the prosthesis, mechanical debridement, and pocket irrigation with a chlorhexidine gel in six patients) and surgical therapy (open flap debridement and soft tissue repositioning in two patients). In one patient the situation led to the loss of the implants and the prosthesis (unaccounted for the survival estimate), with a new prosthesis manufactured to connect to both the remaining implants and the new implants inserted. In

Table 2 Odds ratio (OR) with 95% confidence intervals (CI) for opposing dentition and crown status

Factor	OR	Sig.	95% CI	OR[1]	Sig.	95% CI
			Development group			
Opposing dentition						
Non-ceramic	1.0					
Ceramic	2.04	0.01	1.18–3.54	1.97	0.016	1.14–3.43
Crown status						
Not perforated	1.0					
Screw access opening	1.53	0.100	0.92–2.54	1.45	0.156	0.87–2.41
			Routine group			
Opposing dentition						
Non-ceramic	1.0					
Ceramic	0.36	0.163	0.08–1.52	0.36	0.165	0.08–1.53
Crown status						
Not perforated	1.0					
Screw access opening	1.65	0.204	0.76–3.59	1.65	0.207	0.76–3.59

[1]OR from logistic regression analysis with opposing dentition and crown status included as explanatory variables.

In the development group, the univariate and adjusted analyses disclosed a significant effect for opposing dentition as a risk factor for the incidence of mechanical complications, which remained significant after adjusting for crown status effect.

In the routine group, no relevant effects were found in the univariate or adjusted analysis, meaning that variable (opposing dentition or crown status) had a relevant effect on the model.

Table 3 Estimated fractions for survival using the Kaplan-Meier product limit estimator for the prostheses in the development group

Time (months)	Status (0 = non failure; 1 = failure)	Cumulative proportion surviving at the time		N of cumulative events	N of prostheses at risk
		Estimate	Std. Error		
0	0	–	–	0	66
12	0	–	–	0	64
13	1	0.984	0.016.	1	63
24	0	–	–	1	63
30	1	0.968	0.022	2	61
36	0	–	–	2	60
48	0	–	–	2	57
53	1	0.952	0.027	3	56
60	0	–	–	3	52
72	0	–	–	1	45
73	1	0.930	0.034	4	44
84	0	–	–	4	22
89	1	0.883	0.056	5	19
96	0	–	–	5	11
108	0	–	–	5	3
120	0	–	–	5	2
122	0	–	–	5	1
127	0	–	–	5	0

Table 4 Estimated fractions for survival using the Kaplan-Meier product limit estimator for the prostheses in the routine group

Time (months)	Status (0 = non failure; 1 = failure)	Cumulative proportion surviving at the time		N of cumulative events	N of prostheses at risk
		Estimate	Std. Error		
0	0	–	–	0	59
12	0	–	–	0	59
24	0	–	–	0	56
36	0	–	–	0	52
48	0	–	–	0	25
60	0	–	–	0	4
61	0	–	–	0	2
62	0	–	–	0	1
67	0	–	–	0	0

another patient who lost implants, the prosthesis was attached to the remaining implants without further insertion of implants.

The incidence of biological complications registered in the routine group occurred in 15 patients, ranging from peri-implant pathology (10 patients) to soft-tissue inflammation (five patients). The peri-implant pockets were solved through non-surgical therapy (10 patients) using the same method as described in the development group. No implants were lost after the connection of the prosthesis in the routine group.

Aside from the cases of peri-implant pathology and soft-tissue inflammation, poor oral hygiene was diagnosed in another six patients of the development group and five patients in the routine group. These patients received mechanical debridement and chemical therapy (chlorhexidine) together with reinforcement of the oral hygiene recommendations.

Common to all therapies for solving the biological complications was the possibility to remove and reconnect the prosthesis (retrievability of the prosthesis), which was possible due to the existing screw access openings in the definitive crowns. No functional, esthetic, or comfort complications were registered during the follow-up of this study in the development or the routine group.

Discussion

The survival of the prosthesis in both the development and routine groups is comparable to other rehabilitations of completely edentulous arches,[42–47] and therefore allow us not to reject the null hypothesis. These findings continue to build on the issue of long-term outcomes of implant-supported metal ceramic prostheses manufactured using CAD/CAM technology.

The lower survival rate achieved in the development group is related to the incidence of mechanical complications (most of them crown fractures). This finding influenced the treatment planning in the routine group, where with the introduction of zirconia crowns and controlling for the possible effect of the opposing dentition (excluding metal ceramic implant-supported fixed prostheses), led to a low number of fractures. It was possible to identify the absence of a negative effect of perforating the crowns (screw access openings) on the outcome of the rehabilitations. The survival of the crowns can be compared with other reports that analyzed all-ceramic crown survival in the medium and long term.[30,41] The concept's independence from technique sensitivity (allowing a standardized production) accounts for a higher probability of success and increased predictability in the clinical setting.[28]

The accurate precision of fit in these rehabilitations was related to the welded Ti framework used in this concept, which is described in the literature as achieving superior results when compared to the frameworks made with cast gold alloy.[36] All-ceramic crowns with Procera laminates resulted in a high esthetic result, judged by the absence of esthetic complaints registered in our study. Previous reports acknowledged a superior esthetic level with this concept when compared to the metal ceramic crowns.[38,39] The ceramic fractures were easily repaired due to the concept's flexibility. Those fractures implicating removal of the crown were repaired immediately in the mouth by the dentist with a provisional acrylic crown, and later a ceramic crown was made and cemented. The Procera software saves the files of previously scanned dies, making it easy to manufacture a new coping. The prostheses were never removed from the mouth due to ceramic fractures and most important, not baked again, which would have brought negative consequences for the ceramic. Also, this capacity of repair demonstrated by the structure was an important factor for the patient, as the protocol applied assured a rapid and comfortable repairing.

The reasons for crown fractures (ceramic failures) may be related to technical failure in the manufacturing process, occlusion failure in controlling the occlusion following the guidelines previously presented,[9,10] or parafunctional

movements by the patient.[9,10] All these possible causes could act independently or in association; however, there was a twofold increase in the probability of crown fracture when the opposing dentition was an implant-supported metal ceramic FPD, a situation acknowledged in previous reports,[10] which could imply a lack of proprioception by the patient and/or the lack of shock-absorbing capacity by the prosthesis. It is important to control implant occlusion within physiologic limits and thus provide optimal implant load to ensure long-term implant success, but currently there is no evidence-based implant-specific concept of occlusion.[9] The precision of fit is another important factor to prevent mechanical complications,[6] and our results (taking into consideration the absence of misfit incidences registered in our study) are supported by other studies stating that using CAD/CAM technologies should allow a more uniform passive fit to the prosthesis.[5,48] The method for repairing the chipping of the ceramic gingiva (that created a gap on the affected prosthesis) using a special pink-colored resin composite (Gradia Gum) is not satisfactory in terms of longevity, and future research should focus on better methods to resolve this complication.

The biological complications registered in our study were most likely related to low levels of oral hygiene. Apart from the necessary high levels of oral hygiene self-care from the patient that influence the outcome,[49] the necessity of removing the prostheses in these situations further expresses the need for easy retrievability of these structures, facilitating access to the implants for accurate diagnosis or therapeutic interventions.

The limitations of the study are related to the retrospective design, only one clinical center involved, the shorter follow-up time of the routine group, and the lack of randomization. The methodology implemented with a development and a routine group, was integrated in a concept of rehabilitation with several phases of conception, experiment, evaluation (development group), reconception, and reexperiment (routine group), to resolve the weak points identified in the development group.

The 12 patients lost to follow-up (11% of the sample) account for the good methodological quality of the study, representing less than 20% of the sample size,[50] thus reducing the probability of bias. Future research should focus on the documentation of fixed implant-supported rehabilitations using CAD/CAM technology with long-term outcomes (more than 10 years of follow-up).

Conclusions

Within the limitations of this study, the outcome of a metal ceramic implant-supported fixed prosthesis with a Ti framework and all-ceramic crowns is valid, with a survival estimate of 96.4% overall, 92.4% for the development group at 10 years, and 100% for the routine group at 5 years. The absence of esthetic complaints or misfit, the independence from technique sensitivity (allowing a standardized production), retrievability, and capacity of repairing characteristics prove the viability of this fixed prosthetic solution. When planning the rehabilitation, the existing opposing dentition should be considered, as the presence of a metal ceramic implant-supported fixed prosthesis resulted in a twofold-increased probability of crown fractures. This type of fixed rehabilitation should be further investigated to evaluate its survival with 10 years of follow-up using the current protocol.

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