Complication and Failure Rates with Implant-Supported Fixed Dental Prostheses and Single Crowns: A 10-Year Retrospective Study

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ABSTRACT

Purpose: Clinical studies related to the long-term outcomes with implant-supported reconstructions are still sparse. The aim of this 10-year retrospective study was to assess the rate of mechanical/technical complications and failures with implant supported fixed dental prostheses (FDPs) and single crowns (SCs) in a large cohort of partially edentulous patients.

Materials and Methods: The comprehensive multidisciplinary examination consisted of a medical/dental history, clinical examination, and a radiographic analysis. Prosthodontic examination evaluated the implant-supported reconstructions for mechanical/technical complications and failures, occlusal analysis, presence/absence of attrition, and location, extension, and retention type.

Results: Out of three hundred ninety seven fixed reconstructions in three hundred three patients, two hundred sixty eight were SCs and one hundred twenty seven were FDPs. Of these three hundred ninety seven implant-supported reconstructions, 18 had failed, yielding a failure rate of 4.5% and a survival rate of 95.5% after a mean observation period of 10.75 years (range: 8.4–13.5 years). The most frequent complication was ceramic chipping (20.31%) followed by occlusal screw loosening (2.57%) and loss of retention (2.06%). No occlusal screw fracture, one abutment loosening, and two abutment fractures were noted. This resulted in a total mechanical/technical complication rate of 24.7%. The prosthetic success rate over a mean follow-up time of 10.75 years was 70.8%. Generalized attrition and FDPs were associated with statistically significantly higher rates of ceramic fractures when compared with SCs. Cantilever extensions, screw retention, anterior versus posterior, and gender did not influence the chipping rate.

Conclusions: After a mean exposure time of 10.75 years, high survival rates for reconstructions supported by Sand-blasted Large-grit Acid-etched implants can be expected. Ceramic chipping was the most frequent complication and was increased in dentitions with attrition and in FDPs compared with SCs.

KEY WORDS: dental implant, fixed dental implant supported prosthesis, mechanical complication, prosthesis failure, prosthesis survival, single implant crown, technical complication

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INTRODUCTION

Over the last decade, considerable progress related to reported survival rates of dental implants has been noticed mainly as a result of improved surface characteristics promoting faster tissue integration and stable peri-implant tissues.[1–4]

A recent retrospective publication on survival and success rates observed that in three hundred three partially edentulous patients with five hundred eleven Sand-blasted Large-grit Acid-etched implants, high survival (98.8%) and success (97%) rates were present with over 10 years of function.[5] The rate of biological complications was limited to two implants with suppuration at the time of examination and to seven implants with peri-implant bone loss requiring surgical and anti-infective therapy. These implants presented with healthy peri-implant soft tissues at the 10-year examination.

Utilization of pretreatment concepts, a surgical protocol and supportive therapy in collaboration with referring dentists, resulted in favorable outcomes in this large cohort study of partially edentulous patients. In addition to stable clinical outcomes with the implants, fixation, function, the long-term integrity of the materials, and esthetics of the prosthetic suprastructures are of key interest for the patients.[6–8] Mechanical and technical risks play a major role in implant dentistry as they may lead to increased rates of repairs/remakes and therefore affect the patients time, finance, and even quality of life.[8]

When analyzing pooled data from several long-term clinical studies, the estimated event rates per one hundred reconstructions per year[9] are useful parameters for statistical comparisons of the risk for complication or failure at 3, 5, and 10 years expected with different types of prosthetic reconstructions. In fact, increased failure or complications rates were reported in systematic reviews for certain groups of reconstructions.[10–12] Several risk factors could lead to damage of the integrity of implant-supported reconstructions, whereas the implant and the surrounding tissue may remain unaffected.[8]

The aim of the present study was to assess technical complication and failure rates observed with ceramometal crowns and fixed dental prostheses (FDPs) in a cohort of partially edentulous patients with implant-supported prostheses after a follow-up period of at least 10 years. In addition, risk indicators associated with increased complication rates were evaluated.

MATERIAL AND METHODS

Patient Cohort

The records of all patients, who were surgically treated with implants between May 1997 and January 2001 at the Department of Oral Surgery and Stomatology or at the Department of Periodontology and Fixed Prosthodontics, School of Dental Medicine, University of Bern, were screened. Only partially edentulous patients who had received at least one tissue-level implant with an SLA surface (Straumann Dental Implant System, Straumann, Basel, Switzerland) were eligible for inclusion into the study. The partially edentulous patients had received either single-unit crowns (SCs) or short-span FDPs. About 20% of the reconstructions were fabricated in the dental laboratory of the School of Dental Medicine. The patients were enrolled in a structured maintenance care program, either in private practice or at the University of Bern. Patients were contacted and invited to participate in a comprehensive clinical and radiographic examination. All patients gave written informed consent after being informed in detail about the objectives of the investigation.[5] The informed consent document was written in accordance with the "Declaration of Helsinki" (as adopted by the 18th World Medical Assembly in Helsinki [1964] and as revised in Tokyo [1975], Venice [1983], Hong Kong [1989], Somerset West [1996], Edinburgh [2000], Washington [2002], Tokyo [2004], and Seoul [2008]). A recently published study addressed the survival and success rates obtained with SLA implants inserted in these patients.[5] The present report evaluates the mechanical/technical complication and failure rates of implant supported SCs and FDPs and assesses the risk factors associated with these prosthetic complications and failures.

General Assessment and Prosthodontic Examination

A comprehensive multidisciplinary examination was carried out in all eligible patients. This consisted of an update of the medical and dental history by means of a questionnaire and interview, intraoral photographs, and a prosthodontic examination. A radiographic examination included an orthopantomogram and periapical radiographs of the implants and their reconstructions.

The following parameters were assessed by a prosthodontist: presence/absence of an SC, presence/absence

of an FDP, materials used to fabricate the reconstruction, number of replaced teeth, number of abutments, cemented/transocclusal screw retention/transversal screw retention/mixed tooth-implant supported reconstruction, and presence of a mesial/distal cantilever extension.

During the prosthodontic examination, the implant-supported SCs and FDPs were also examined for any complications or failures.[8]

Technical complications included:

- loss of retention;
- fracture and/or chipping of ceramic; and
- fracture of the framework.

Mechanical complications included:

- loosening of an occlusal screw;
- fracture of an occlusal screw;
- loosening of an abutment;
- fracture of an abutment; and
- fracture of an implant.

A failure was defined as an event leading to:

- the loss of the reconstruction;
- the need to renew the entire implant-supported reconstruction as well as reported "repairs" of the reconstruction; and
- the explantation/loss of the implant and therefore also the loss of the implant-supported reconstruction.

Patients were also asked to mark any negative events that had occurred in relation to the implants or the suprastructures during the last 10 years. This included any losses, repairs or remakes of the reconstructions. Together with the questionnaire and the patient's charts, any events that had occurred during the 10 years of exposure were noted.

Occlusal Analysis

The occlusal analysis comprised the assessment of overjet and overbite in millimeter in static occlusion. Attrition was estimated as absent, localized, or generalized. Guidance was assessed as either mutually protected with group function or bilaterally balanced.

The opposing dentition was categorized according to the presence of naturally restored or unrestored teeth, implant-supported restorations, or removable partial denture.

Statistical Analysis

The SAS/STAT® program was used for the statistical analysis (SAS® Version 9.2, SAS Institute Inc., Cary, NC, USA). Descriptive statistics included: frequencies, means, and survival rates. For the evaluation of the frequencies and percentages of the different subgroups, we used SAS PROC FREQ, evaluating the significance with a chi-square calculation and Fisher's exact test where appropriate. Significance level was set at 0.05. For the calculation of the odd ratios and their confidence interval, a logistic regression analysis was performed (SAS PROC LOGISTIC).

RESULTS

Patients

A total of three hundred fifty eight patients met the inclusion criteria according to their records. Of those, 55 patients were unavailable for the 10-year examination for various reasons.[5] In total, three hundred three patients (one hundred sixty female and one hundred forty three male patients) were examined (Table 1).

Implants

In these three hundred three patients, five hundred eleven titanium dental implants with an SLA surface had been inserted more than 10 years ago. The mean follow-up time for the three hundred ninety seven

TABLE 1 Descriptive Overview of Number of Patients, Type of Reconstructions, Location, and Observation Time

	n
Patients	303 (160 female, 143 male)
Implants inserted	511
Original reconstructions	397
Original crowns	268
Original FDPs (I-I = 127; I-T = 2)	129
Reevaluated reconstructions	389
Reevaluated crowns	261
Reevaluated FDPs	128
Maxilla/mandible	187/202
Anterior/posterior	81/308
Mean observation time	10.75 years

I-I = implant supported/I-T = tooth supported.

reconstructions was 10.75 years, ranging from 8.4 to 13.5 years (Table 1).

Reconstructions

A total of three hundred ninety seven fixed implant-supported reconstructions were originally inserted including two hundred sixty eight SCs, one hundred twenty seven implant-supported FDPs, and two mixed implant-tooth-supported FDPs. Three hundred eighty nine reconstructions were available for reevaluation and comprised of two hundred sixty one SCs, 47 double-unit crowns, and 57 three-unit, 21 four-unit, two five-unit, and one six-unit FDPs. With respect to location, one hundred eighty seven reconstructions had been delivered in the maxilla and two hundred two in the mandible. A total of 81 restorations had been installed in anterior and three hundred eight in posterior sites (Table 1).

Failures of the Reconstructions

Six reconstructions were lost as a consequence of the failure of the corresponding supporting implant, noted between 4 and 10 years after insertion of the implants (Table 2).

Two reconstructions were lost because adjacent teeth failed and new reconstructions were made. In one case, a three-unit FDP was reduced to an SC. The distal part of the FDP was removed because of chronic cheek biting (Table 2).

Five reconstructions were renewed 8 to 11 years after implant insertion (Table 2).

Four reconstructions were noted as repairs 9 years after implant insertion (Table 2).

These 18 reconstructions were considered as failures because the integrity of the reconstructions no longer provided function, or the original reconstruction was lost (failure rate of 4.5% for the 10-year period).

Complications of the Reconstructions

At the 10-year examination, 98 reconstructions showed at least one mechanical/technical complication (Table 4). The most frequently observed complication was ceramic chipping (79) (Figure 1A) followed by occlusal screw loosening (10) and loss of retention (eight; Table 3). Screw fracture, abutment loosening/fracture and "unknown reason" were noted once in one reconstruction. This resulted in a total complication rate of 24.7%, which when combined with the 4.5% failure

TABLE 2 Overview of Failures of the Implant-Supported Reconstructions

Patient Number	Sex	Position	Type of Reconstruction	Date of Implant Placement	Date Failure Noted	Reason/Notes
213	M	46	Crown	13.06.00	03.2009	Implant failure
79	F	26	Crown	03.03.99	04.01.10	Implant failure
92	F	25	Two-unit FDP	25.01.00	06.2008	Implant failure
304	F	46	Crown	04.11.99	23.06.06	Implant failure
305	M	21	Crown	23.11.99	2008	Implant failure
306	M	24	Crown	01.03.00	17.11.04	Implant failure
37	M	11	Crown	20.08.98	2008	Loss of adjacent tooth, new rec
155	F	44	Crown	21.01.08	17.09.09	Loss of adjacent tooth, new rec
5	F	34 × 36	Three-unit FDP	17.06.97	NA	Cheek biting, rec shortened to crown 34
58	M	21	Crown	27.11.98	NA	Redone
253	M	32	Crown	12.10.00	2008	Redone
39	M	11	Crown	03.09.98	2009	Redone
123	F	26	Crown	03.09.99	09.2008	Redone
99	M	25	Crown	17.06.99	2008	Redone
140	M	46	Crown	09.11.99	2009	Repaired
7	F	45 46	Two-unit FDP	15.07.97	2006	Repaired
90	F	23 24 25	Four-unit FDP	05.05.99	2008	Repaired
80	M	36 37	Two-unit FDP	03.03.99	06.2008	Repaired

FDP, fixed dental prosthesis.

TABLE 3 Mechanical and Technical Complications after 10.75 Years

	n	%
Loss of retention	8	2.06
Ceramic chipping	79	20.31
Occlusal screw loosening	10	2.57
Occlusal screw fracture	1	0.26
Abutment loosening	1	0.26
Abutment fracture	1	0.26
Unknown reasons	1	0.26

rate, concluded in a 70.8% success rate after 10 years (Table 4).

Risk Factors

Ceramic fractures demonstrated a prevalence of 10.9%, 21.9%, and 26.9% in dentitions with no, localized, and generalized signs of attrition, respectively (Table 5). Attrition was associated with a statistically significant increase in the rate of observed ceramic fractures ($p = 0.015$, Wald chi-square).

Table 6 illustrates the rate of the ceramic fractures for single- and multiple-unit reconstructions. Multiple-unit reconstructions had a statistically significantly higher risk for ceramic chipping compared with SCs ($p = 0.0074$, Wald chi-square).

When the reconstructions were sorted into presence/absence of cantilever extensions (Table 7), cemented or screw retained (Table 8) and reconstructions with different opposing dentitions no statistically significant differences were observed. The role of potential risk factors influencing ceramic fracture rates was tested with the use of logistic regression analysis. A statistically significant influence of attrition (p value: 0.002) and size of the reconstruction (i.e., SC vs FDP) (p value: 0.001) was observed, whereas anterior/posterior location of the reconstruction and gender were not associated with an increased risk for ceramic fractures ($p > 0.05$) (Table 9).

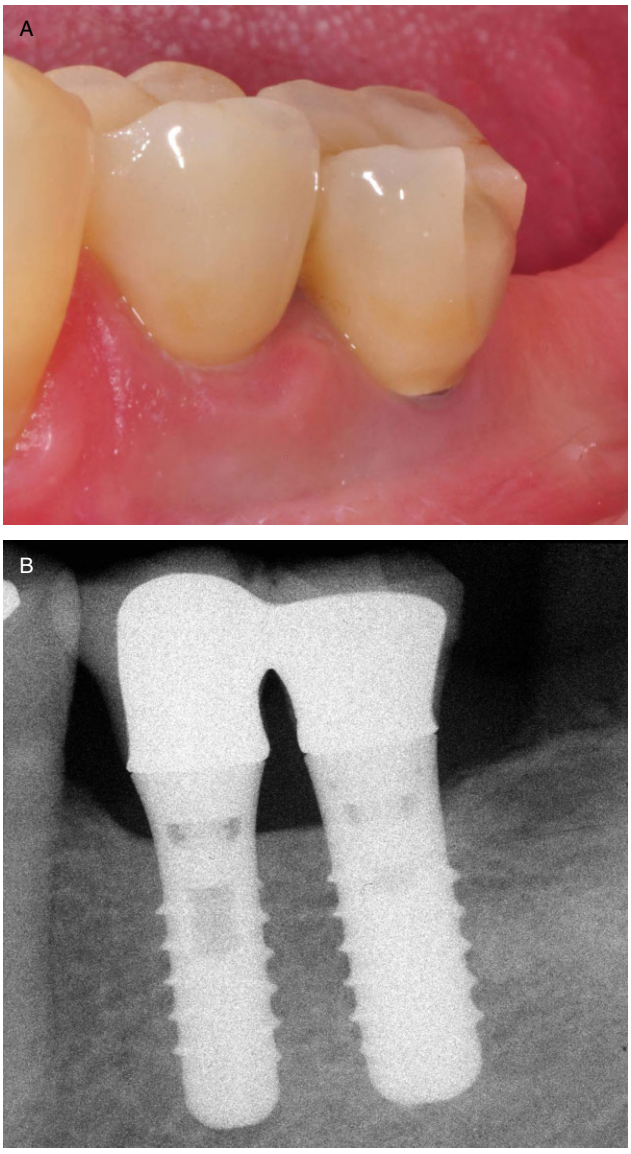

Figure 1 *A* and *B*, Clinical picture and radiograph of the present study showing ceramic fracture.

TABLE 4 Overview of Failure, Survival, Complication, Success Rates after 10 Years

	n
Total no.	397
Failures	18
10-year failure rate	4.5%
10-year survival rate	95.5%
Number of reconstructions with at least one complication	98
10-year complication rate	24.7%
No. of complications and failures	114 (29.2%)
10-year success rate	70.8%

DISCUSSION

The overall survival rate after 10 years of the reconstructions in this retrospective study was 95.5%, and the prosthetic success rate was 70.8%.

TABLE 5 Results of Attrition Score and Influence on the Fracture/Chipping Rate

No Attrition	Local	Generalized	
101 (26.3%)	164 (42.7%)	119 (31.0%)	Reconstructions (%), 384 observations
11 (10.9%)	36 (21.9%)	32 (26.9%)	Reconstructions with fracture of ceramic veneer (%) 79 observations
Wald chi-square $p < 0.015$			Confidence interval for odds ratios:
			No attrition versus localized: .21 – 0.90
			No attrition versus generalized: .16 – 0.70
			Localized versus generalized: .44 – 1.32

In a recent systematic review of 26 clinical studies, the estimated survival rate of implant-supported SCs was 94.5% after 5 years of function.[10] Another systematic review on implant-supported FDPs reported an estimated 10-year survival rate of 86.7%,[11] which when compared is lower than that reported in the present study. Interestingly, patients with implant-supported FDPs of that systematic review[11] were at higher risk of having complications compared with patients with tooth-supported FDPs.

TABLE 6 Description of Type of Reconstruction (Single- or Multiunit) and Reconstructions with Ceramic Fracture

Crown (I)	FDP (>I)	
261 (67.1%)	127 (32.9%)	Reconstructions (%)
44 (16.9%)	36 (28.3%)	Reconstructions with fracture of ceramic veneer (%)
Wald chi-square $p < 0.01$		Confidence interval for odds ratios
		Crown versus FDP 0.30–0.83

TABLE 7 Number of Reconstructions with Extensions and of Those Affected by Ceramic Fracture

No Extension	Extension	
340 (87.4%)	49 (12.6%)	Reconstructions (%)
68 (20.0%)	11 (22.5%)	Reconstructions affected by fracture of ceramic veneer (%)

Of the observed 18 failures, nine were unrelated to a prosthetic cause. Only the remaining nine failures could be associated with a prosthetic cause. Although a low prosthetic-related failure rate (e.g. 4.5%) was observed in the present investigation, complications occurred frequently. The most frequent complication was ceramic chipping (Figure 1A,B). The second most frequent complication was screw loosening, followed by loss of retention. The prosthetic implant components therefore were able to resist forces over the 10-year follow-up period. All reconstructions were made of PFM (porcelain-fused-to-metal) except one; however, due to the retrospective study design, the exact material and manufacturing process was unknown. A total of 98 reconstructions showed at least one complication, therefore resulting in a total complication rate of 24.7%. This corresponds with a 70.8% prosthetic success rate at completion at the 10-year follow-up period. Similar complication rates were presented in the systematic review by Pjetursson and colleagues (2007)[11] where the most frequent technical complications were fractures of the veneering material, abutment or screw loosening, and loss of retention. Comparing the rate of ceramic fracture or ceramic chipping of conventional tooth-supported FDPs and solely implant-supported

TABLE 8 Description of Retention Type of Reconstructions

Cemented	Transocclusal Screw	Transversal Screw	Mesostructure	
311 (80%)	68 (17.5%)	9 (2.3%)	1 (0.2%)	Reconstructions (%)
64 (20.7)%	13 (19.1%)	2 (22.2%)	0 (0%)	Reconstructions with fracture of ceramic veneer (%)

TABLE 9 Results of Logistic Regression Analysis

Dependent	Fracture of ceramic veneer	0 = absent	
		1 = present	
Independent	Attrition	0 = no attrition	
		1 = localized attrition	
		2 = generalized attrition	
	Reconstruction	0 = crown	
		1 = FDP	
	Anterior 01	0 = posterior	
		1 = anterior	
	Sex	1 = female	
		2 = male	
Analysis of maximum likelihood estimates		odds ratio	*p*
Attrition	0 vs 2	0.287	0.002
	1 vs 2	0.597	n.s.
Reconstruction	0 vs 1	0.481	0.001
Sex	1 vs 2	0.814	n.s.
Anterior01	0 vs 1	1.424	n.s.

n.s.: not statistically significant.

FDPs, the tooth-supported FDPs had a significantly ($p = 0.042$) lower 5-year risk of ceramic fracture or chipping of 2.9% compared with 8.8% for the implant-supported FDPs.[11]

Regarding implant supported SCs, the cumulative incidence of screw or abutment loosening was 12.7%, ceramic or veneer fractures was 4.5%, and 0.35% for screw or abutment fracture in a 5-year study.[10] In a systematic review, the estimated percentage of complication-free single-implant restorations after 3 years was reported as 97.6% for internal connection implants (mean follow-up time range of 3–10 years).[13]

Possible explanations for "ceramic chipping" may be the presence of a nonanatomic substructure design, unsupported ceramic veneering, weaker porcelain, thermal expansion/contraction mismatches and/or poor porcelain bonding and patient characteristics (e.g., parafunctional activity).[14–16] The validity of these etiologies cannot be verified for the present investigation as the manufacturing process and material choice is unknown.

Another important aspect is the overall design of the FDPs accounting for the importance of geometric features on the maximum stress and the corresponding probability of failure.[17] The span length of the implant-supported reconstructions was detected as a potential risk factor for the development of ceramic fractures. In the present report, multiple-unit reconstructions had a significant higher risk for ceramic chippings compared with SCs ($p = 0.0074$ Wald chi-square) (Table 6) and an association with the ceramic fracture rate could be confirmed via logistic regression analysis (Table 9). In a systematic review reporting on mechanical and technical risks, it was shown that 25% of implant-supported SCs demonstrated a mechanical/technical complication after a 5-year period when compared with 44% of three- to four-unit implant-supported FDPs. Therefore, the authors concluded that longer reconstructions seemed to be more prone to mechanical/technical complications than SCs.[8]

This study presented a significant influence of the presence and severity of attrition with ceramic chipping. In dentitions without signs of attrition, the reconstructions showed a 10.9% ceramic fracture rate, whereas in dentitions with localized or generalized signs of attrition, the fracture rate was 21.9% and 26.9%, respectively.

In general, the severity of attrition was associated with a statistically significant increase in the rate of observed ceramic fractures ($p = 0.015$, Wald chi-square) and is, therefore, found to be a potential risk factor. An explanation might be hypothesized that if there is an increase in attrition in the dentition, the implant-supported reconstruction has more stress and load from

the time of delivery. As opposing natural teeth can intrude, the load will be equalized and therefore no chipping might be expected. On the other hand, if the opposing dentition is also an implant-supported reconstruction, it will not intrude. The mean values of an axial displacement of teeth are approximately 25 to 100 μm, compared with a dental implant of 3 to 5 μm.[18,19] In addition, the presence of periodontal ligament with teeth can serve as a shock absorber, transferring the occlusal stresses along the axis of the tooth and distributing them. Around osseointegrated implants, a periodontal ligament is absent and, therefore, the occlusal load is concentrated at the crest of the surrounding bone without dissipation of the occlusal stresses. In addition, implants lack the neurophysiologic receptor function of the periodontal ligament, which transmits information of proprioceptive nerve endings to the central nervous system.[18,20] The presence or absence of the periodontal ligament makes a significant difference in tactile sensitivity between implants and natural teeth.[19,20] The patient is therefore unable to feel if the implant supported reconstruction is in a hyperocclusion. If the opposing dentition is also an implant-supported reconstruction, then ceramic chipping might be the outcome. Therefore, although the dentition of the opposing jaw was recorded in the present study, no statistically significant association was observed. In the present report, influencing potential risk factors were compared with the ceramic fracture rate using logistic regression analysis. The outcome confirmed the significant influence of attrition and size of the reconstruction (crown vs FDP); however, the additionally tested parameters of anterior/posterior location, occlusal scheme, type of opposing dentition, and gender could not be associated with an increased risk for ceramic fractures (Table 9).

The final aspects of the statistical analysis including extension, screw versus cement retention, anterior versus posterior location, and gender revealed no influence on the ceramic fracture rate (Tables 7–9). When grouping the reconstructions into extension present yes/no (Table 7), cement or screw retention (Table 8), different situations in the opposing jaw, and dentitions with static or dynamic occlusions, no statistically significant difference was observed.

Cantilever extensions are frequently used in implant restorations and should be handled with caution. Previously published overall incidences of technical complications were higher in implant-supported reconstructions with cantilever extensions than without;[8,12,21,22] however, this could not be verified in the present study (Table 7).

The main limitation of this clinical investigation is its retrospective design. As a result, no information is given regarding the material properties, prosthetic design, or manufacturing process of the reconstructions. Furthermore, the patient's preexisting clinical and anatomical situation, the selected occlusal scheme of the inserted implant reconstructions, and the treatment concepts used during planning of the case are unknown. Recommendations for future research projects might be to perform a prospective designed study with the collection of all available data concerning the materials used (abutment/framework/veneering material), the laboratory process (design of prostheses and details of manufacturing process) and adding to the documentation of the chipping events the location, the degree of severity, and if it is a adhesive or coadhesive nature.

CONCLUSIONS

The survival rate of implant-supported ceramometal reconstructions was high, 10 years after implant placement.

Technical/mechanical reasons accounted for only 50% of the failed reconstructions. Chipping of the ceramic veneer was the most frequent technical complication and was more frequently observed in FDPs compared with SCs as well as being directly related with attrition. Almost no complications or failures were related to the prosthetic components of the implant system, indicating that they were able to withstand the forces placed upon them.

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