Titanium- and zirconia-based implant-supported fixed dental prostheses. A randomized, prospective clinical pilot study

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Abstract

◉ The aim of this study was to compare porcelain-veneered implant-supported FDPs based on zirconium dioxide and titanium respectively.

Sixteen patients received 18 implant-supported partial fixed dental prostheses (FDPs); 8 titanium-based and 10 zirconia-based. The FDPs were randomized between the two material groups. Follow-up of the patients was performed at 3 months and thereafter once a year. An assessment protocol based on the California Dental Association (CDA) quality assessment system was used.

Results: All patients were seen at follow-up. The mean time of clinical service at follow-up was 15,2 months (range 12-24 months). All restorations were in place and all patients were satisfied with the treatment. No technical complications were noted in either group. Minor biological complications, in the form of plaque and/or mucositis, not affecting the survival of the restorations were noted for six of the titanium-based restorations and two of the zirconia-based restorations. The difference between the two material groups was not statistically significant.

The outcomes of both materials were comparable. Short term data from this study suggests that porcelain-veneered implant-supported partial FDPs based on zirconia and titanium are satisfactory and equal treatment options. This conclusion is however preliminary as it is based on a small number of patients and short-term follow-up. Long-term follow-up of larger groups of patients is needed before more definite conclusions can be made.

Key words

Titanium, yttria stabilized tetragonal zirconia, porcelain veneer, dental implants, fixed dental prostheses

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Implantat-stödda broar baserade på titan respektive zirkoniumdioxid. En prospektiv klinisk randomiserad pilot-studie

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Sammanfattning

◎ Målsättningen med studien var att jämföra implantat-stödda partiella broar av titan-porslin respektive yttria-stabiliserad zirkoniumdioxid med ytporslin. Sexton patienter fick sammanlagt 18 broar; 8 av titan-porslin och 10 av yttria-stabiliserad zirkoniumdioxid-porslin. Broarna fördelades randomiserat till respektive material-grupp. Patienterna följdes upp och kontrollerades en första gång efter 3 månader och därefter en gång per år. Ett bedömningsprotokoll baserat på California Dental Association (CDA) kriterier användes.

Alla patienter genomförde kontrollbesöken. Genomsnittlig uppföljningstid var 15,2 månader (12-24 månader). Alla konstruktioner var i funktion vid uppföljning och alla patienter var nöjda med behandlingen. Inga tekniska komplikationer noterades i någon av grupperna. Biologiska komplikationer av ringa betydelse, plack och/eller mucosit, som inte påverkade konstruktionernas överlevnad noterades vid 6 av titan-keramikbroarna och 2 av zirkonia-porslinsbroarna. Skillnaden var inte statistiskt signifikant.

Sammanfattningsvis kan vi i denna studie konstatera att båda materialen fungerade jämförbart. Data från denna studie antyder att implantat-stödda partiella broar av titan-porslin respektive zirkoniumdioxid med ytporslin uppvisar goda resultat på kort sikt. Studier med fler patienter och längre uppföljningstid rekommenderas emellertid innan definitiva slutsatser kan dras.

Introduction

Fixed dental restorations can be made from many different materials. There is extensive evidence of the excellent long-term results for conventional high-noble-alloy-based porcelain-fused-to-metal (PFM) restorations (2,20,24). As some studies have reported on adverse reactions against gold however (12), attention has been focused on even more biocompatible materials as alternatives.

In recent years fixed dental prostheses (FDPs) based on yttria-stabilized tetragonal zirconia polycrystals (zirconia) have become popular thanks to excellent biocompatibility, good aesthetics and sufficient strength for posterior restorations (13). An increasing amount of studies on zirconia-based restorations show similar survival rates as conventional high-noble-alloy-based PFM restorations, the gold standard (5).

The risk of complete failure is minimal for zirconia-based restorations. Few studies on tooth-supported and none of the studies on implant-supported zirconia-based restorations have registered any complete fractures. However, almost all studies report fractures of the veneering porcelain and implant-supported zirconia-based restorations have been shown to be especially prone to veneering material fractures (3,5).

Few veneering material fractures have led to the removal of restorations, most can be polished or left untreated, a few have been repaired (1). The importance of the veneering material fractures should therefore not be over-emphasized as many patients are unaffected by them and even unaware of them (1). They are however important to discuss as a veneering material fracture creates a rough surface, and sometimes sharp edges, that often leads to some need for adjustment. It may also affect aesthetics and/or lead to functional impairment, with loss of occlusal and approximal contacts, to such an extent that replacement would be necessary.

Another type of restoration that satisfies the demand for excellent biocompatibility is the titanium-based PFM FDP. Unfortunately however, these restorations have also shown more fractures of the veneering material compared to high-noble-alloy-based PFM FDPs (6,25).

To assist the clinician in making choices and selecting materials, studies comparing success and complication rates for FDPs made of different materials within the same study would be valuable. Unfortunately there is a lack of such studies, especially for implant-supported restorations. The aim of the present study was therefore to compare porcelain-veneered implant-supported FDPs based on zirconia and titanium respectively. The hypothesis was that there would be no differences in clinical performance between the two types of restorations.

Material and methods

Twenty implant-supported FDPs were planned to be made; 10 zirconia-based and 10 titanium-based during the period January 2009 to June 2011. The patients were recruited consecutively from the Prosthodontic Specialist Centres, Public Dental Health Service, in Norrköping and Linköping, Sweden. The inclusion criteria were indications for one or more two- to five unit implant-supported restorations supported by two to three implants. Exclusion criteria were factors preventing implant placement, i.e physical or mental illnesses preventing surgical treatment as judged by medical doctor, and/or allergies towards any of the materials planned to be used.

During the study period, January 2009 to June 2011, 16 patients met the inclusion criteria and accepted participation, 8 women and 8 men between the ages of 21 and 85 years. The status of the opposing jaw varied from natural teeth with or without minor fillings to tooth-supported metal-ceramic FDPs, implant-supported metal-ceramic FDPs and removable complete denture. (Table 2)

The patients were informed about the protocol of the study, the risks with and alternatives to the proposed treatment, and all gave their informed consent. Ethical approval of the study was obtained from the Regional Ethics Committee in Linköping, Sweden (M51-08).

Dental implants (Brånemark System Mk III, RP or NP, Nobel Biocare Nordic AB, Göteborg, Sweden) were installed in a one-stage surgical procedure according to the surgical instructions of the manufacturer. The healing time before prosthodontic treatment was a minimum of 3 months in the lower jaw and 6 months in the upper jaw. The surgical treatment was performed by three dentists, specialists in periodontology. Four dentists, specialists in prosthodontics, performed the prosthodontic treatment. One dentist treated 12 of the patients, one treated two patients, and the other two treated one patient each.

When the prosthodontic treatment began, FDPs were randomly assigned to patients meeting the inclusion criteria, using a list of uniform distributed random numbers, made in collaboration with a statistician. (Table 1)

Table 1.
Randomization protocol.

FDP nr	Treatment
1	A
2	B
3	B
4	A
5	A
6	B
7	A
8	B
9	B
10	B
11	B
12	A
13	A
14	B
15	B
16	B
17	A
18	A
19	A
20	A

A: titanium-based
B: zirconia-based

Table 2. Status of the opposing jaw – presence of natural teeth or restorations – in relation to type of provided treatment; zirconia- or titanium-based implant-supported (IS) fixed dental prostheses (FDP).

Status oppsing jaw	Zirconia-based IS FDP	Titanium-based IS FDP
Natural teeth	3	4
Tooth-supported metal-ceramic FDP	2	1
Implant-supported metal-ceramic FDP	4	3
Complete denture	1	

Table 3. Surface according to the assessment protocol.

Score	Criteria	Outcome
A Excellent	The surface of the restoration is intact	Success
B Acceptable	Superficial fracture that does not affect aesthetics or function.	Survival
C Retrievable	Superficial fracture affecting aesthetics and/or function but can be adjusted by polishing or repaired.	Survival
D Unacceptable	Fracture affecting aesthetics or function to such an extent that replacement is necessary.	Failure

Full-arch impressions on implant level were made with a polyether impression material (Impregum™ Penta, 3M ESPE, St. Paul, MN, USA) in disposable trays (Tray Aways®, The Bosworth Company, Skokie, Illinois, USA) using the open-tray technique. Impressions of the opposite jaw were made with alginate (Aroma Fine, GC, Fuji Oyama, Japan) in rigid stainless steel trays (COE, GC, Fuji Oyama, Japan). Finally inter-occlusal registrations in centric relation were made in aluminium wax (Alminax®, Associated Dental Products, Wiltshire, Great Britain).

The laboratory procedures were carried out at two commercial dental laboratories (Boxholm Dental, Boxholm, Sweden and DP Nova, Sjöbo, Sweden). Eighteen implant-supported fixed dental prostheses were made for the 16 patients. Ten of the patients received 10 zirconia-based (yttria-stabilized tetragonal zirconia) FDPs (Procera Implant Bridge Zirconia, Nobel Biocare Nordic AB, Göteborg, Sweden) and eight patients received 8 titanium-based (commercially pure titanium, grade 2) FDPs; 4 Procera Implant Bridge (Procera Implant Bridge Titanium, Nobel Biocare Nodic AB, Göteborg, Sweden) and 4 I-Bridge (Biomain AB, Helsingborg, Sweden). The restorations were made at implant level, without abutments. The frameworks were tried in the mouth and intraoral radiographic examinations were made to check the marginal fit. Any frameworks not exhibiting optimal fit were to be remade.

The frameworks were veneered with porcelain. Zirox NR (Wieland, Pforzheim, Germany) and HeraCeram (HeraeusKulzer GmbH, Hanau, Germany) veneering porcelain was used for the zirconia frameworks and Espident Triceram (Dentaurum, Ispringen, Germany) and GC Initial Ti (GC, Fuji Oyama, Japan) for the titanium frameworks. Firing was done according to the respective manufacturer´s protocols following recommendations concerning times and temperatures. A coating agent/liner was used as recommended to enhance adherence between veneer and core. The titanium frameworks were ground and sandblasted and Triceram bonder (Dentaurum, Ispringen, Germany) and Ti bonder (GC, Fuji Oyama, Japan) applied according to the respective manufacturers protocol and subsequently fired. The zirconia frameworks veneered with HeraCeram were steam-cleaned and then Zr Adhesive (HeraeusKulzer GmbH, Hanau, Germany) was applied and fired. The zirconia frameworks veneered with Zirox NR were sandblasted with aluminium oxide, 110µm at 1 bar pressure and subsequently fired. Recommended protocols for time for cooling phase were followed.

The completed restorations were fitted and temporarily sealed with plastic tube and temporary fillings (Systemp Inlay, Ivoclar Vivadent, Schaan, Liechtenstein). After three months the restorations were

re-examined, the centric screws were retighten to 35Ncm and the access holes sealed with plastic tube and composite fillings (Filtech Supreme, 3M ESPE, St. Paul, MN, USA).

Follow-up examinations were performed after three and twelve months and will be performed again after 36 and 60 months. The surface of the restorations and periimplant conditions were rated as excellent, acceptable, retrievable or not acceptable according to a protocol based on the California Dental Association (CDA) quality assessment system (18). (Table 3,4)

Success was defined as the restoration having no complications, i.e. only A ratings according to the protocol. Survival was defined as the restoration remaining in-situ with complications that do not affect function or that can be repaired, i.e. B and/or C ratings. Failure was defined as the restoration having been removed or with complications of such severity that removal is necessary, i.e. D ratings.

Differences between the groups were calculated using Fisher's exact probability test.

Results

Eight patients received 8 titanium-based PFM FDPs (2-5 units) and 10 patients received 10 zirconia-based porcelain-veneered FDPs (2-3 units).

All patients attended the follow-up. The mean time of clinical service at follow-up was 15,2 months (range 12-24 months). All restorations were in place and all patients were satisfied with the treatment. No technical complications, such as loosening of the abutment screws or fractures of the veneering material were noted. All surfaces were rated A according to the protocol (Figure 1).

Figure 1.

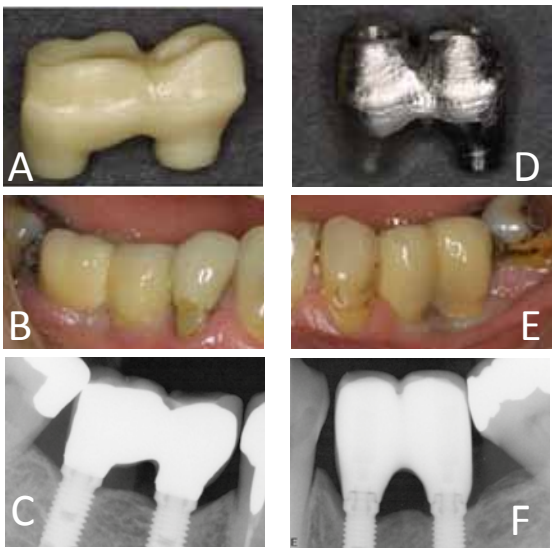

Figure 1 A-F
A: Buccal view of Procera Implant Bridge Zirconia (before veneering)
B: Buccal view of Procera Implant Bridge Zirconia (in place)
C: Radiograph of Procera Implant Bridge Zirconia at 1-year follow-up
D: Buccal view of Procera Implant Bridge Titanium (before veneering)
E: Buccal view of Procera Implant Bridge Titanium (in place)
F: Radiograph of Procera Implant Bridge Titanium at 1-year follow-up

Table 4. Periimplant conditions according to the assessment protocol.

Score	Criteria	Outcome
A Excellent	No plaque and/or mucositis.	Success
B Acceptable	Presence of plaque and/or mucositis.	Survival
C Retrievable	Marginal bone loss which responds to treatment – implants and restoration remain in-situ.	Survival
D Unacceptable	Marginal bone loss that does not respond to treatment leading to removal of implant and restoration.	Failure

Table 5. Firing temperature and coefficient of thermal expansion (CTE) of the veneering porcelains.

Veneering porcelain		Firing tempereature (C°)	CTE (µm/m.K)
Titanium frameworks	Triceram	760	9,6
	GC Initial Ti	780	8,6
Zirconia frameworks	Heraceram	880	10,5
	Zirox NR	900	10,5

Minor biological complications, not affecting the survival of the restorations were noted. Eight of the ten zirconia-based FDPs, with 16 abutments, showed excellent periimplant health and were rated A according to the protocol. Two zirconia-based FDPs, with 4 abutments, showed plaque and/or mucositis and were rated B. Two of the eight titanium-based FDPs, with 11 abutments, showed excellent periimplant health and were rated A according to the protocol. Six titanium-based FDPs, with 9 abutments, showed plaque and/or mucositis and were rated B (Table 6).

The difference between the groups was not statistically significant. The patients showing presence of plaque and/or mucositis received treatment and no further complications have been noted to date.

Discussion

Zirconia-based FDPs offer many advantages such as excellent biocompatibility and good aesthetics and have become an interesting treatment alternative to PFM FDPS. Survival rates are comparable but an increased risk of veneering material fractures has been reported for zirconia-based restorations (5). The occurrence of veneering material fractures has been especially high for implant-supported restorations according to previous reports (3,9,10).

The same problems have been noted for titanium-based restorations, for tooth-supported as well as implant-supported FDPs (6,25,27). To avoid exposing the zirconia and titanium frameworks to unfavourably high temperatures during porcelain firing, creating undesirable phase transformation, porcelain of low firing temperature is often used. Glass modifiers are added to lower the firing temperature and this modification affects the mechanical properties which is a risk factor for veneer fractures (8).

Using veneering materials with different microstructure and firing temperatures to increase the strength and minimize the risk of fractures has been suggested (Table 5). Laboratory studies comparing veneering materials with different microstructure, firing temperatures and coefficient of thermal expansion have however not found any significant differences (11,21).

In the present study no fractures of the veneering material were noticed. This is in contrast to earlier publications where veneering material fractures have been reported to occur frequently for zirconia- and titanium-based restorations (5,6,9,10,25). A possible explanation for the improved results in the present study compared to earlier studies could be the fact that this study was initiated recently when the knowledge of different factors of possible influence on veneering materials as well as on how to design, handle and produce zirconia- and titanium-based restorations has improved compared to what was known at the time the above mentioned studies were initiated (15). For titanium-based restorations, the high frequency of complications in the form of veneering material fractures has by some authors been explained by inexperience in using low-fusing

Table 6. Placement of FDPs, materials and prescence of minor biological complications.

Patient	FDP nr	Material	Framework	Porcelain					
1	1	Zr	Procera	HeraCeram	35	(36)	37		
2	2	Zr	Procera	HeraCeram	45	44			
3	3	Ti	I-Bridge	Triceram	34	(35)	36►		
4	4	Zr	Procera	Zirox	45►	44►			
5	5	Ti	I-Bridge	TriCeram	11	(21)	22		
6	6	Ti	I-Bridge	GC	14►	13►	12►		
7	7	Zr	Procera	Heraceram	24	25			
8	8	Zr	Procera	Heraceram	34►	35►			
9	9	Ti	Procera	GC	45►	44			
10	10	Ti	Procera	Trieram	22	(23)	24►	25	
	11	Zr	Procera	HeraCeram	16	(15)	14		
11	12	Ti	Procera	Triceram	13►	12	(11)	(21)	22►
12	13	Zr	Procera	Zirox	47	(46)	45		
13	14	Zr	Procera	Zirox	34	(35)	36		
14	15	Zr	Procera	Zirox	45	44			
	16	Ti	Procera	Triceram	34	35			
15	17	Ti	I-Bridge	Triceram	15	14►	13		
16	18	Zr	Procera	Zirox	15	14			

► Denotes presence of plaque and/or mucositis

porcelains, suggesting the influence of a "learning-curve" (27).

Many factors influencing the risk of veneering material fractures in zirconia restorations have been discussed (15). Recently much attention has been focused on the design of the supporting substructure and the thickness of the veneering material (23). Veneering materials are brittle and of relatively low strength. The compressive strengths of veneering materials are higher than their tensile strength so it is important to design the framework to avoid tensile stress. An anatomical design of the substructure will provide support for the veneer and create conditions for mainly compressive forces within the veneering material. Several studies have high-lighted the importance of an adapted, anatomical design of the substructure (11,16,22). The cores of the FDPs in the present study were all designed to have an anatomical shape allowing for support of the veneering material.

The design of the substructure also controls the thickness of the veneering material. Thick layers of porcelain veneered on frameworks with low thermal diffusivity such as zirconia, may generate high residual tensile stresses which can contribute to fractures of the veneering material (23). The FDPs in the present study were designed to have a uniform layer of veneer with a minimal thickness of 1mm but not exceeding 1,5 mm.

Uncontrolled stresses will increase even further if the firing process and subsequent cooling are not performed appropriately (23). Many manufacturers have adapted the cooling process according to these findings to reduce stresses after porcelain firing. The FDPs in the present study were fired and subsequently cooled according to new adapted protocols as recommended by the respective manufacturers.

The FDPs in the present study were manufactured keeping these factors in mind and the results are promising. However, relatively few patients are included, the size of the restorations is limited, and the follow-up time is short so conclusions are preliminary.

The restorations in the present study were screw-retained and placed on implant level, i.e. without abutments. A screw-retained restoration facilitates retrieveability in case of complications. The technique also has the advantage that there is no risk of retained excess cement which has been suggested to increase the risk of periimplantitis (26). Some have however, suggested that restorations placed directly on implant level without abutments show increased crestal bone resorption compared to control groups with abutments (14). In the present study, no crestal bone resorption was noted for either treatment group. The follow-up time was however short. There is a risk of bone resorption developing over time and this factor will be addressed again in future follow-up.

Plaque and/or mucositis were registered around eight of the FDPs; six of the titanium-based and two of the zirconia-based. This numerical difference between the groups was not statistically different - possibly due to the small sample of restorations.

Ceramic materials have been found to accumulate less plaque and plaque with reduced vitality, compared to other restorative materials (4,7,17). The clinical significance is uncertain however. A review comparing metal and ceramic abutments found a numerical difference with higher frequency of biological complications around metal abutments compared to ceramic abutments but the difference was not statistically significant (19).

Aspects of the method used

Twenty implant-supported FDPs were originally planned to be made; 10 zirconia-based and 10 titanium-based FDPs during the period January 2009 to June 2011, and the randomization protocol was designed accordingly. At the end of the study period only 16 patients with 18 FDPs had met the inclusion criteria. This may limit the possibilities of identifying possible differences and affect the conclusions drawn. There were differences between the two material groups with respect to size of the restorations. The titanium-based FDPs were 2-5 units whereas the zirconia-based FDPs were 2-3 units. Although no differences were noted in the short term this may affect results over longer term.

The patients in the present study were all treated by specialists at a clinic for prosthetic dentistry. This may limit the applicability of the treatment outcome compared to other groups of treatment providers (28).

Conclusion

Short term data from this study suggests that porcelain-veneered implant-supported FDPs based on zirconia and titanium are satisfactory and comparable treatment options. This conclusion is however preliminary as it is based on short-term follow-up of a small number of patients. Long-term follow-up of larger groups of patients is needed before more definite and general conclusions can be made.

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