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Zirconia dental implants: a clinical one year follow-up report and patient satisfaction evaluation

Key words: zirconia dental implants, clinical study, *in vivo*, patient satisfaction, zirconia

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Abstract

Objectives: The aim of this study was to compare zirconia dental implants and natural teeth (control) with regard to several clinical parameters (i). Furthermore, periimplant papilla dimensions and Periotest values (ii) as well as patient esthetic and general satisfaction (iii) were evaluated.

Material and methods: 38 adults (56.24 ± 10.6 years) with 106 full-ceramic implants participated in this study. The implants (IMP) were *in situ* for 14.25 ± 6.82 months on average. The clinical parameters plaque index (PI), bleeding on probing (BOP) probing pocket depth (PPD), probing attachment level (PAL) and creeping or recession (CR/REC) of the gingiva were detected and compared with natural control teeth (CT). Furthermore, a papilla index (PAP) according to Jemt and the Periotest values (PTV) were assessed. In order to evaluate patient satisfaction with this treatment method, each patient answered a questionnaire, especially designed for this investigation.

Results: The survival rate after time of follow-up was 100%. No statistical significance was found between implants and teeth regarding **BOP** ($mBOP_{IMP}$ 14.77 ± 20.17% vs. $mBOP_{CT}$ 5.97 ± 6.37%), **PPD** ($mPPD_{IMP}$ 2.49 ± 0.7mm vs. $mPPD_{CT}$ 2.48 ± 0.51mm) and **PAL** ($mPAL_{IMP}$ 2.63 ± 0.87mm vs. $mPAL_{CT}$ 2.76 ± 0.7mm). However, a statistical significance between the 2 groups was detected regarding **PI** (mPI_{IMP} 19.79 ± 21.76% vs. mPI_{CT} 36.33 ± 17.43%) and **CR/REC** (mCR/REC_{IMP} 0.14 ± 0.55mm vs. mCR/REC_{CT} 0.26 ± 0.26mm). Mean **PAP** was 1.76 ± 0.55 whereas the m**PTV** was -1.31 ± 2.24 (range from -5 to +6).

The questionnaire revealed that the majority of the patients were satisfied with the overall treatment and all patients would recommend it to friends and relatives, if indicated.

Conclusions: One-piece zirconia dental implants exhibited similar and in regard to adhesion of plaque and creeping attachment even better biological parameters when compared to natural teeth. The Periotest values testify a firm connection to the bone, while the results for the papilla index did not fulfil the expectations. The patients were quite satisfied with the overall result. So, zirconia dental implants may serve as an alternative to implants made of titanium. However, long-term experience is needed to support these findings.

For several years now, titanium implants are regarded as an established and successful treatment option in implant dentistry in terms of osseointegration and healing time. Commercially pure titanium (c.p. Ti) as well as its alloys reveal an excellent biocompatibility, high corrosion-resistance and good mechanical properties (Leventhal 1951, Brånemark, et al. 1977, Adell, et al. 1981, Kasemo & Lausmaa 1988, Buser, et al. 1997, Akagawa & Abe 2003). By forming an oxide layer when being in contact with oxygen, the material becomes inert and is therefore very biocompatible and offers a strong bone to implant contact (Brånemark, et al. 1969). Several studies and long-term clinical experience approve the adequacy of this material for dental implants (Albrektsson, et al. 1988). In some cases, however, titanium may cause a reaction of intolerance which usually is not an allergy, but a consequence of an increased inflammatory process that is conducted by the proinflammatory cytokines TNFα and IL1β (Sterner, et al. 2004, Taki, et al. 2007). Other studies report local accumulation of titanium in neighbouring tissues and titanium deposition in regional lymph nodes after insertion of titanium screw implants (Weingart, et al. 1994, Bianco, et al. 1996). Yet the clinical relevance of these findings is still to be clarified (Andreiotelli, et al. 2009). Beyond, there is an increased demand of patients for metal-free reconstructions. The dark colour of titanium, however, may lead to a grayish discoloration of the periimplant gingiva finally provoking some nonsatisfying esthetical results.(McCartney, et al. 1993, Yildirim, et al. 2000, Henriksson & Jemt 2003, Glauser, et al. 2004, Park, et al. 2007). During the last few years full ceramic dental implants experienced a renaissance, especially since zirconia reached strongly improved material properties for the first time. Several advantages like the ivory colour, the low affinity to dental plaque (Rimondini, et al. 2002, Scarano, et al. 2003) which might lead to a promising soft tissue management and the absolute biocompatibility, qualify this material for dental implants, especially since the modern yttria-strengthened zirconia achieved strongly improved material properties compared to alumina (Al_2O_3). Alumina has already been utilized as dental implant material (The Tübingen Immediate Implant; (Schulte & Heimke 1976). Even though osseointegrative properties of these implants revealed promising results (Schulte, et al. 1978), biomechanical qualities were not sufficient for long-term success and sustainability (Andreiotelli, et al. 2009).

Besides alumina, zirconia belongs to the family of oxide ceramics. It offers several advantages compared to other ceramic materials, due to the mechanical properties and the transformation toughening mechanism. Zirconia reaches twice the bending strength and fracture toughness of alumina (Tinschert, et al. 2001). It occurs in three forms: monoclinic, tetragonal and cubic. Pure zirconia is monoclinic at room temperature. The monoclinic phase is stable up to a temperature of 1170°C. Above this temperature, it transforms into the tetragonal phase and then into the cubic phase at a temperature of 2370°C. During cooling the tetragonal phase turns into the monoclinic phase, with a volume expansion of approximately 4%. The addition of oxides like calcium, magnesium or yttrium, enables the stabilisation of the tetragonal (or the cubic) phase at room temperature. Zirconia that is considered to be used in dentistry is stabilized with yttrium at the tetragonal phase (Y-TZP: yttria-strengthened tetragonal zirconia polycrystals) and is completely constituted by tetragonal grains. One of the advantages of this material is the self-repairing mechanism. A processing crack causes a stress-induced transformation from the tetragonal into the monoclinic phase which, as described before, leads to a volume expansion that compresses and stops the processing crack at its apex (Piconi & Maccauro 1999). The addition of alumina (Al_2O_3) improves the material properties by increasing the bending strength and the durability (Table 1).

Table 1. Survey of the different material properties of the TZP and the TZP-A ceramics according to manufacturer information (Metoxit, Thayngen, Switzerland; see also: Kohal, et al. 2009)

Properties	Unit	TZP	TZP-A
Components		ZrO_2/Y_2O_3	$ZrO_2/Y_2O_3/Al_2O_3$
Composition	%	95/5	95/5/0.25
Density	g/cm^3	6.05	6.05
Porosity	%	0	0
Grain size	µm	0.40	0.35
Vickers hardness	Hv	1200	1200
Compressive strength	MPa	2000	2000
Bending strength	MPa	1000	1200
Modulus of elasticity	GPa	200	210

A further advancement of the mechanical properties can be achieved by using a special sintering process named “Hot Isostatic Pressing” (HIP) in combination with an inert atmosphere (argon) under high pressure. The HIP-process reduces the porosity as well as material defects and increases the density (Piconi & Maccauro 1999).
Clinical studies about zirconia dental implants are still rare. According to a recent review (Andreiotelli, et al. 2009) only 3 retrospective cohort investigations were identified in the international literature (Mellinghoff 2006, Oliva, et al. 2007, Lambrich & Iglhaut 2008).
The authors of this review stated that “the study methodology for the clinical investigations included in this review has to be rated as questionable especially for the zirconia implant studies. Because of the high risk of bias the scientific value of these reports has to be considered as low” whereas randomized-controlled clinical trials for ceramic implants do not exist (Andreiotelli, et al. 2009). This present study features a controlled clinical trial though without randomization. The aim of this investigation was to compare zirconia dental implants and natural teeth (control) with regard to plaque index, bleeding on probing, probing pocket depth, probing attachment level and creeping or recession of the gingiva (i). Furthermore, periimplant papilla dimensions and Periotest values (ii) as well as patient esthetic and general satisfaction (iii) were evaluated.

Material and methods

Patients

38 healthy adult partially edentulous patients (20 female, 18 male) with an inconspicuous anamnesis participated in this study. The mean age was 56.24 ± 10.6 years (range 33-74 years; median 58 years). The clinical protocol was approved by the Ethics Committee of the University Hospital Frankfurt (Germany). The study aims and design were discussed with the patients, and written consent was obtained. All patients that fulfilled the inclusion criteria (Table 2) participated in this study.

Table 2. Inclusion criteria that were applied in this investigation

Inclusion criteria
- Minimum age of 18 years (or older)
- Patient with at least one Z-Look implant *in situ* (including prosthetical reconstruction) and at least one remaining natural tooth
- Prosthetic reconstruction *in situ* for at least 6 months
- No periodontal disease
- No general disease
- No pregnancy
- Periodic intake of drugs that may fudge the investigated clinical parameters (e.g.: antibiotics, immunosuppressants, anticonvulsants or ataractics)

- Patient was treated by the same dentist (surgical intervention and prosthetical reconstruction)
- Patient agreed to participate in the study (written consent was obtained)

Implants

Prior to the beginning of this study, 1 implant got lost due to the non-compliance of 1 patient who did not constantly wear the protective device that was needed to make sure that the implants are immobilized during the healing period. Therefore, this implant was not assessed in this investigation. A total of 106 implants were examined at all. 53 implants were inserted in the maxilla and 53 in the mandible (Table 3).

Table 3. Distribution of all 106 implants in the different regions of the upper and the lower jaw

Maxilla		Mandible	
Front	**Side**	**Front**	**Side**
18	35	12	41
53		53	

In this study the "Z-Look 3" implant system (Z-Systems, Oensingen, Switzerland; Fig. 1-3) was examined. It is a one-piece full ceramic dental implant made of yttria-strengthened zirconia (Y-TZP-A-Bio-HIP®) with a sandblasted intra-osseous section and a polished transgingival/abutment portion. An external hexagon surface that must be abraded after implant insertion is needed to place the implant into the bone. The surgical procedure strictly complied with the recommendations of the manufacturer. The implants were in situ for 14.25 ± 6.82 months on average. All implants were restored with all-ceramic superstructures (Cerec, Sirona, Bensheim, Germany) 4 months (lower jaw) and 6 months (upper jaw) after the surgical intervention. At the time of assessment, the final restorations had been in place for 9.16 ± 4.92 months on average.

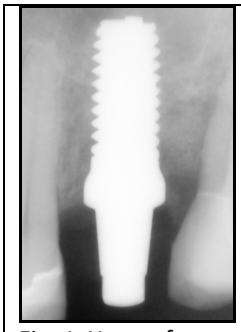

Fig. 1. X-ray of a zirconia implant in the region of the first molar in the upper jaw.

Fig. 2. Z-Look implant in the canine region of the upper jaw. Picture taken after implant exposure for the scanning process.

Fig. 3. 6 Z-Look implants in the lower jaw. Picture taken a half year after implant insertion. The periimplant soft-tissue reveals healthy conditions without signs of plaque, inflammation or bleeding.

Clinical examinations

The clinical investigation comprised plaque index, bleeding on probing, probing pocket depth, probing attachment level, creeping or recession of the gingiva and a papilla index. The Periotest method was used to describe the stability of the implants in their osseous environment. Furthermore, a questionnaire especially designed for this study was distributed among the patients. 106 implants (IMP) and 822 natural control teeth (CT) were investigated at all. The clinical examination was carried out by a single examiner and included the assessment of the following parameters at all implants and remaining teeth.

The plaque index (PI) was evaluated after revealing the plaque with a plaque disclosing solution (Hager & Werken, Duisburg, Germany). Presence or absence (dichotomous index) of plaque and bleeding on probing (BOP) was documented at 4 aspects per implant/tooth and calculated in % per site. The parameters probing pocket depth (PPD) and probing attachment level (PAL) were also assessed at 4 aspects of each tooth or implant using a periodontal probe (PCB 12; Hu-Friedy, Leimen, Germany). So a recession or a creeping (CR/REC) of the gingiva could be calculated. The changeover from the implant shoulder to the crown was used as reference for the attachment level. The aforementioned clinical parameters were compared to the natural teeth using them as reference.
To describe the morphology of the papillae surrounding the implants, the papilla index according to Jemt was used (Table 4). It indicates to what extent the interproximal space is filled with the papilla. Predominantly, this index was developed to describe the soft tissue of implant-supported single tooth restorations (Jemt 1997).

Table 4. Description of the particular index values for the papilla index

Index value	Description
0	no papilla is present
1	less than half of the papilla is present
2	at least half of the papilla is present, but the entire proximal space is not filled up
3	the papilla fills up the entire proximal space
4	hyperplastic papilla

The implant stability was detected with the Periotest method at each implant (Schulte & Lukas 1992). All patients were asked to fill out a questionnaire (Table 6) that was especially designed for this study. It contained questions concerning the overall patient satisfaction with this treatment method. A 6-grade scale, ranking from positive (grade 1: “very good”) to negative (grade 6: “unsatisfactory”), was used for most of the questions, while others were to be answered by yes or no.

Statistical evaluation

SPSS for Windows 17.0 statistical software package was used for data analysis. The Gaussian distribution was analyzed using the Kolmogorov–Smirnov test. The majority of the data and their differences were non-normally distributed. Therefore non-parametric tests were applied. The level of statistical significance was set at 0.05. The Wilcoxon signed ranks test was employed for comparison of plaque index, bleeding on probing, probing pocket depth, probing attachment level and creeping or recession of the gingiva at teeth and implants.

Results

The evaluation of the results demonstrated that the plaque accumulation at zirconia implants was significantly lower (P=0.001; Fig. 4) compared to natural teeth (mPI_{IMP} 19.79 ± 21.76% vs. mPI_{CT} 36.33 ± 17.43%). However, although bleeding on probing occurred more often at implant reconstructions than around teeth ($mBOP_{IMP}$ 14.77 ± 20.17% vs. $mBOP_{CT}$ 5.97 ± 6.37%), but a statistical significance could not be detected in this case (P=0.214; Fig 4). The implants as well as the natural teeth in this study predominantly featured probing pocket depths and attachment levels between 2 and 3 mm ($mPPD_{IMP}$ 2.49 ± 0.70mm vs. $mPPD_{CT}$ 2.48 ± 0.51mm; $mPAL_{IMP}$ 2.63 ± 0.87mm vs. $mPAL_{CT}$ 2.76 ± 0.70mm). In both cases, a statistical significance could not be detected (P=0.694 respectively P=0.478; Fig. 5).

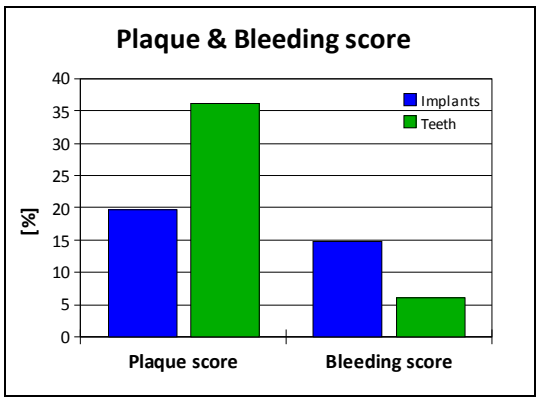

Fig. 4. Comparison of plaque and bleeding score of the implants and the natural teeth.

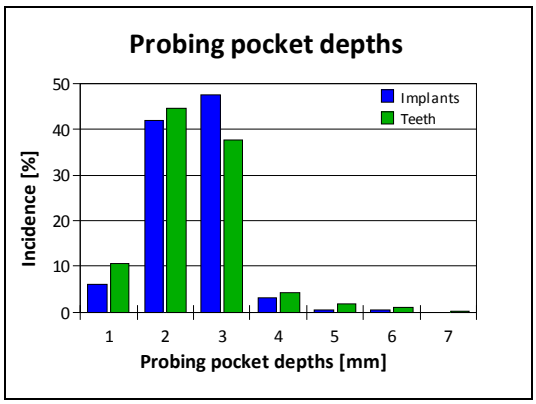

Fig. 5. Comparison of probing pocket depths assessed at the implants and the natural teeth.

A creeping attachment of the gingiva was evaluated at 7.1% of the implants. Compared to the natural teeth (mCR/REC_{MP} 0.14 ± 0.55mm vs. mCR/REC_{CT} 0.26 ± 0.26mm), a statistical significance could be detected in favour of the zirconia implants (P=0.042). On average nine months after prosthetical reconstruction, 13.2% of the implants offered a papilla that filled up the entire proximal space (papilla score 3; Fig. 6). 56.6% of the implants featured index value 2 (mPAP 1.76 ± 0.55). However, right before the scanning process for the prosthetical maintenance, a gingivectomy was needed for implant exposure.
The full ceramic implants featured Periotest values (mPTV -1.31 ± 2.24) that ranged from -5 in the lower jaw to +6 in the upper jaw (Fig. 7). Table 5 discloses all clinical parameters.

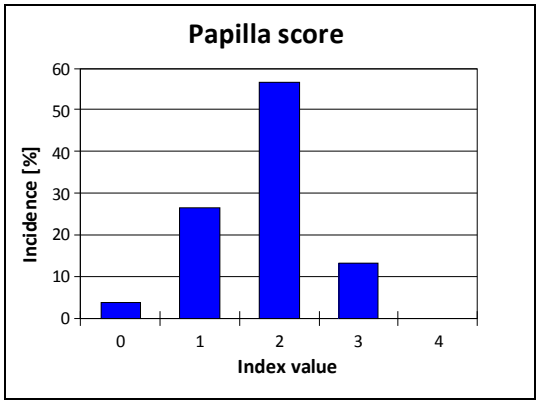

Fig. 6. Survey of the Values detected fort he papilla score. The implants of this study predominantly featured index value 2.

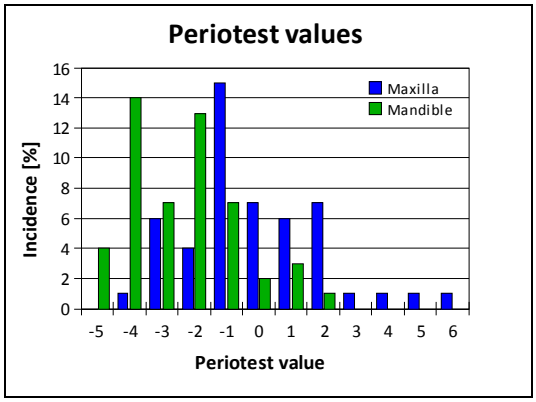

Fig. 7. Periotest values detected in the upper and the lower jaw.

Table 5. Overview of the different parameters at implants and teeth; statistical significance of comparisons between implants and teeth was set at P<0.05

Parameter [unit]	Implants				Teeth				P-Value
	Average and standard deviation	Median	Min	Max	Average and standard deviation	Median	Min	Max	
PI [mm]	19.79 ± 21.76	16.67	0	87.50	36.33 ± 17.43	34.61	0	72.73	0.001
BOP [%]	14.77 ± 20.17	0	0	50	5.97 ± 6.37	3.85	0	31.82	0.214
PPD [mm]	2.49 ± 0.70	2.50	1	6	2.48 ± 0.51	2.42	1	7	0.694
PAL [mm]	2.63 ± 0.87	2.50	1	6	2.76 ± 0.70	2.66	1	8	0.478
CR/REC [mm]	0.14 ± 0.55	0	-2	+3	0.26 ± 0.26	0.20	-1	3	0.042
PAP	1.76 ± 0.55	1.71	0	3	-	-	-	-	-
PTV	-1.31 ± 2.24	-1	-5	+6	-	-	-	-	-

The surgical intervention as well as the esthetical outcome of the individual prosthetic rehabilitation and the overall result reached a grade point average between 1.34 and 1.37. However, the protective device received a higher grade point average with a statistical spread (see standard deviations and median). The majority of the patients wore the protective device as they were commended to and did not feel disturbed. Except for one individual, the patients were collectively satisfied with this treatment method whereas all patients would recommend it to friends or relatives (Table 6).

Table 6. Survey of the different answers to the questionnaire; the questions 1 to 5 were rated with a 6-grade scale from 1 ("very good") to 6 ("unsatisfactory")

Question	Rating (grade point average)	Median	Min	Max
1) Comfort of surgical intervention?	1.34 ± 0.53	1	1	3
2) Management of the protective device?	1.76 ± 0.91	2	1	5
3) Aesthetics of the protective device?	2.11 ± 0.92	2	1	4
4) Aesthetics of the prosthodontics?	1.34 ± 0.58	1	1	3
5) Overall result?	1.37 ± 0.49	1	1	2
Question	**Answer**			
6) Did the protective device disturb you?	Not at all: 42.10%	Often: 0%		
	Seldomly: 21.10%	Very often: 7.90%		
	Casually: 26.30%	Permanently: 2.60%		
7) Wearing time of the protective device?	24h: 79%	12h: 5.30%		
	20h: 0%	8h: 10.50%		
	16h: 2.60%	4h: 2.60%		
8) Accept this treatment method again?	Yes: 97.40%	No 2.60%		
9) Recommend this treatment method?	Yes: 100%	No: 0%		

Discussion

In this study, it could be demonstrated that one-piece zirconia dental implants exhibit similar and in regard to adhesion of dental plaque and creeping attachment even significantly better biological parameters, when compared to remaining natural teeth. Although more bleeding on probing could be detected at implant sites, this had no negative effect on the overall success rate of the implant reconstructions. An additional subjective assessment by means of a standardized questionnaire disclosed that patients were quite satisfied with the treatment outcome.

Nowadays, full-ceramic restorations are frequently used in prosthodontics. According to various studies, the results seem to be as favourable as they are with conventional metal or metal-ceramic restorations (Wagner, et al. 2003, Arnelund, et al. 2004, Bindl & Mormann 2004). Furthermore, all-ceramic materials are also used in oral surgery as material for full-ceramic dental implants (Olive & Aparicio 1990, Kohal & Klaus 2004). Currently, these implants undergo a renaissance especially since zirconium dioxide has reached strongly improved mechanical properties compared to alumina (Tinschert, et al. 2001). Several manufacturers offer these implant systems, but there are only a few *in vivo* studies in humans. So, not all of the results in this examination can be directly compared to those of trials with zirconia dental implants, since appropriate studies and comparable results are still missing. For this reason most of the results must be compared to studies with titanium dental implants.

No biological complications were observed in this investigation. The implants showed a significantly lower plaque accumulation than the natural teeth.

A low affinity of dental plaque to ceramic surfaces is in accordance to findings of a study dealing with the bacterial adhesion on zirconia and titanium. *In vivo* Y-TZP surfaces accumulated significantly fewer bacteria than titanium, when placed for 24 hours in the premolar and molar region of human subjects (Rimondini, et al. 2002). Another clinical human study could confirm these results. Zirconia and titanium disks were placed in the oral cavity. After 24 hours plaque accumulation was detected. The zirconia disks showed significantly less adhesion and accumulation of bacteria compared to titanium disks (Scarano, et al. 2004). A previous *in vivo* study could also observe a statistical significantly higher plaque score at the natural teeth compared to titanium implant-supported reconstructions with all-ceramic and metal-ceramic crowns (Sailer, et al. 2009). A further investigation with ITI titanium dental implants could support these findings although a statistical significance could not be detected (Brägger, et al. 1997). Accordingly, a lower bleeding score could have been anticipated at the implants, but the opposite was the case in this investigation. Although a statistical significance could not be determined, bleeding on probing occurred more often at the implants than at the natural teeth. This is contrary to findings from another study with full ceramic dental implants (Blaschke & Volz 2006). Yet, a clear comparison of own results with those of Blaschke & Volz seems to be difficult, since in the corresponding study vital data concerning e.g. location of implants and control teeth, as well as assessment of clinical parameters and inclusion/exclusion criteria are not clearly stated. Nevertheless, in further investigations (Sailer, et al. 2009, Zembic, et al. 2009) the authors could also demonstrate more bleeding on probing at titanium implant-supported reconstructions with zirconia abutments compared to the natural teeth and reconstructions with titanium abutments. These observations were documented with clinical follow-up time-point of 1 year and 3 years. Other clinical trials could also assess more bleeding on probing at reconstructions with titanium dental implants compared to the remaining dentition (Brägger, et al. 1997).

Altogether, the results for PI and BOP in this study are quite similar to recent investigations with titanium implants (Brägger, et al. 1997, Sailer, et al. 2009). The increased bleeding tendency at the implants might be in consequence of the anatomy and morphology of the periimplant soft tissue structures. Unlike natural teeth, dental implants do not possess a compact barrier against penetration properties of the oral cavity. In fact, the periimplant soft tissue acts as a cuff-like barrier (Berglundh, et al. 1991). In contrast to the periodontal attachment, there is no connective tissue fiber insertion to the implant surface. The periimplant soft tissue possesses a lower number of blood vessels (Berglundh, et al. 1994, Moon, et al. 1999) and cells, but a higher amount of collagen (Berglundh, et al. 1991, Lindhe & Berglundh 1998). The lack of connective fiber insertion and decreased vascular supply may lead to a greater susceptibility to plaque-induced inflammation and bleeding. Furthermore, the periimplant mucosa contains significantly enhanced numbers of various inflammatory cells (Liljenberg, et al. 1996).

The probing pocket depths as well as the measurements for the attachment level at implants and teeth were quite similar to each other. Almost 96% of the probing pocket depths at the implants ranged between 2 or 3 mm. This is in agreement to the findings at the natural teeth and suggests a very stable situation at implants and teeth. These results are not in accordance to other studies, as significantly higher PPD and PAL were found at titanium dental implants compared to the natural control teeth (Brägger, et al. 1997, Sailer, et al. 2009). It should be kept in mind though, that the probing depths around the implants are not only caused by the periimplant hard and soft tissue, but also by the construction principle of the investigated implant.

As zirconia implants are said to have favourable soft tissue reactions caused by the low plaque affinity and their inert and biocompatible material properties (Blaschke & Volz 2006), the existence of a creeping attachment and morphology of the papilla was of interest. 7.1% of the investigated implants featured a creeping attachment of the gingiva. In this case, a statistical significance for the benefit of the implants could be detected. Brägger et al. could not reveal a statistically significant difference for the comparison of the recessions at titanium implants and natural teeth (Brägger, et al. 1997). So, it can not be alleged that a ceramic surface solely leads to a perfect soft tissue result (papilla index of 3) after time of follow-up of 14.25 ± 6.82 months, but it should be mentioned that, right before the scanning process for the prosthetical reconstruction, a gingivectomy was needed for implant exposure. The papilla index showed an optimal situation of the papillae (papilla index 3) at only 13.2% of all investigated interproximal spaces, whereas a papilla index of 2 was detected predominantly (56.6%). 26.4% interproximal spaces evaluated an index value of 1 and a missing papilla was detected at 3.8% of all interproximal spaces. A hyperplastic papilla (papilla index 4) could not be evaluated. The findings for the papilla index did not fulfil the expectations as only 13.2% of all investigated interproximal spaces showed an optimal result. So, after time of follow-up, the zirconia surface does not act as a guidance path for the growth of the soft tissue. A clinical study dealing with interproximal tissue dimensions in relation to adjacent titanium implants in the anterior maxilla and patient esthetic evaluation revealed that a papilla index of 2 led to quite satisfying esthetic results among the polled patients (Kourkouta, et al. 2009). However, another study about regeneration of gingival papillae after single-implant treatment, using the papilla index according to Jemt, could demonstrate the development of the papilla score at titanium implants after a longer period of time (Jemt 1997). These results indicated a significant spontaneous regeneration of papillae (P<001) after a mean follow-up period of 1.5 years with a mean papilla score that increased from 1.52 to 2.47. The results demonstrated that soft tissue changes in a systematic manner during the time period between insertion of the crowns and follow-up 1 to 3 years later. 58% of the papillae in that investigation indicated an optimal situation (papilla index of 3). The implants in this clinical study had been restored with the superstructure for a period of 9.16 ± 4.92 months on average. Adjacent follow-ups may show whether the papillae will develop in the same way as they did at the titanium implants in the aforementioned study. Certainly, the development of an optimal morphology of the papilla does not only depend on the material of the implant, the abutment or the crown. Other factors like the surgical intervention (Becker & Becker 1996), the date of follow-up after prosthetical reconstruction (Jemt 1997), the distance between the adjacent implant or tooth (Tarnow, et al. 2000) and the vertical distance from the contact point to the crest of bone (Tarnow, et al. 1992) are of importance, too.

The Periotest values ranged from -5 to +6. Due to the different cortical bone structure, the lowest values were detected in the lower jaw (-2.45 on average) and the highest values were detected in the upper jaw (-0.14 on average). This is in accordance to recent studies about titanium implants that evaluated higher PTV in the lower jaw than in the upper jaw due to the different cortical bone structure (Aparicio 1997). Only 4% of the Periotest values were higher than +2. There are different data reports about Periotest values for osseointegrated implants. Several authors report different values that range from -8 to +9 to describe successfully osseointegrated implants (Olive & Aparicio 1990, Tricio, et al. 1995, Snauwaert, et al. 2000). The osseointegrative potential of ceramic surfaces is well-known in the literature. A lot of studies describe the reaction of bone to zirconia. In the majority of the cases these are histologically evaluated animal studies (Akagawa, et al. 1998, Scarano, et al.

2003, Gahlert, et al. 2007, Depprich, et al. 2008, Sollazzo, et al. 2008, Rocchietta, et al. 2009). These studies could reveal that bone reacts similarly (or even better) to zirconia as it does to titanium (percentage of bone–implant contact)(Andreiotelli, et al. 2009). Altogether, the results from this study suggest a quite strong connection of the zirconia implants to the surrounding bone (Fig. 7). The results of further investigations might show whether the implants with a Periotest value higher than +2 may lead to implant success or not.
A survival rate of 100% at the investigated implants after one year follow-up is not that meaningful and should not be overestimated as long as the results for the long time success are missing. Clinical investigations report survival rates from 84.4% in the maxilla respectively 98.4% in the mandible after 21 months (Lambrich & Iglhaut 2008) to 98% after 1 year (Olive & Aparicio 1990).
The questionnaire revealed that the patients were quite satisfied with the surgical intervention, the esthetics of the prosthetical reconstruction and the overall result. The assessment of the protective device, however, was judged with a higher grade point average (1.76 respectively 2.11). These results can still be appraised as acceptable, especially since the removable protective device is a temporary solution. Most of the patients wore the protective device as they were advised to and did not feel disturbed by it. Certainly, the compliance of the patients in regard to the use of the protective device seems to be of great importance, since one patient lost an implant prior to the beginning of the study, for the reason that he did not wear the protective device constantly. The fact that only one patient would not accept this treatment method again, but all patients would recommend it to friends or their relatives supports the idea of this treatment method. A clinical trial revealed that 93.3% of the patients would recommend the (titanium) implant procedure to another patient (Kourkouta, et al. 2009). A 10-year prospective cohort study reached similar results with ITI® titanium implants. 97% of the 104 patients were satisfied with the esthetics of the treatment whereas 94% would be willing to undergo this treatment again. 89% would recommend the treatment method to relatives and friends (Pjetursson, et al. 2005).

Conclusions

Clinical parameters of one-piece zirconia dental implants feature values that are quite similar compared to natural control teeth. No statistical differences were found concerning the parameters bleeding on probing, probing pocket depth and probing attachment level at implants and teeth (control). Zirconia dental implants though, revealed a significantly lower plaque index and significantly better values in regard to creeping or recession of the gingiva. The Periotest values prove a strong connection to the surrounding bone. As for the promising soft tissue management, the results fell short of expectations. Alleged disadvantages of a one-piece implant system, like the transgingival healing period, are not necessarily evaluated as a negative aspect by the patients. In contrast, the patients are quite satisfied with the treatment. However, long-term experience is needed to support these findings or to reveal potential disadvantages of zirconia, like the aging in a clammy environment. Further investigations have to show whether the newly developed two-piece full ceramic implants (e.g. Dentalpoint, Zurich, Switzerland with the Zeramex® implant system or BPI, Sindelfingen, Germany with the HZI implant system) will prove themselves as more adequate than one-piece systems, or not. Further investigations should also evaluate if a significantly lower plaque score at implant sites also leads to a lower amount of bacteria in the periimplant sulcus compared to the natural teeth, which may be an excellent basis for long-term success.

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