Cemented vs screw-retained zirconia-based single implant reconstructions: A 3-year prospective randomized controlled clinical trial

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Cemented vs. screw-retained zirconia-based single implant reconstructions: a 3-year prospective randomized controlled clinical trial.

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Abstract

Objectives:

The objective of the present randomized clinical trial was to test whether or not the use of screw-retained all ceramic implant-borne reconstructions results in clinical, technical, and biologic outcomes similar to those obtained with cemented all ceramic reconstructions. The hypothesis was that there is no difference in clinical, technical and biological parameters between the two types of retention.

Materials and methods:

Forty-four patients randomly received 20 cemented (CR) and 24 screw-retained (SR) all ceramic single crowns on two-piece dental implants with non-matching implant-abutment junctions. All patients were recalled after crown insertion, at 6 months, 1 year as well as at 3 years. At these visits, biological and radiographic evaluations were performed. Technical outcomes were assessed using modified USPHS (United States Public Health Service) criteria. Data were statistically analyzed with Wilcoxon-Mann-Whitney, Wilcoxon and Fisher exact tests.

Results:

During 3 years of follow-up, 8 patients (18.2%) lost the reconstruction due to technical (6 patients, 13.6%, 2 CR and 4 SR group) or biological complications (2 patients, 4.5%, only CR group). Thirty-two subjects with 18 SR and 14 CR reconstructions attended the FU-3Y, whereas 4 patients (9.1%, 2 SR, 2 CR) were not available (drop-outs). Biological, technical and radiographic outcomes did not differ significantly between the groups ($p>0.05$). One implant (2.3%) was lost in the CR group. One more cemented crown (2.3%) had to be

removed because of peri-implant disease. Six patients (13.6%) lost the reconstructions due to a fracture of the zirconia abutment (4 SR, 2 CR). The mean marginal bone level at 3 years was -0.4 mm (-0.5; -0.3) in group SR and -0.4 mm (-0.6;-0.3) group CR (p=0.864).

Conclusions:

At 3 years, CR and SR exhibited similar survival technical, biological and radiographic outcomes. The rate of technical complications was high in both groups.

INTRODUCTION

Implant-supported single crowns became a valid treatment option for single-tooth replacement due to their excellent clinical long-term results [1-4]. Implant-borne reconstructions can either be screw-retained or cemented. Metal abutments are considered to be the gold standard and demonstrate excellent survival rates in all regions of the jaw[1, 2, 5, 6]. Zirconia abutments were later introduced and are associated with a favorable biocompatibility on the level of the hard and soft tissues[7-10]. A recent systematic review reported similar 5-year failure rates, as well as a similar number of technical complications for ceramic and metal implant abutments. However, ceramic abutments demonstrated significantly more fractures, as well as a higher incidence of biological complications [6]. Nevertheless, ceramic abutments are frequently used in the esthetic region because of the beneficial effect on the esthetic outcome, predominantly in cases with thin facial mucosa[5].

The newest generation of CAD/CAM systems offers two types of retention for implant-borne reconstructions: i) custom-made zirconia abutments in combination with a cemented crown; ii) screw-retained all-ceramic reconstructions. Available data out of systematic reviews suggested more biological complications in case of cemented reconstructions and a higher rate of technical complications for screw-retained reconstructions[6, 11]. However, none of the fixation methods showed a clear advantage over the other. Up to date, there is a lack of studies evaluating screw-retained and cemented all ceramic reconstructions on two-piece dental implants with non-matching implant-abutment junctions.

The aim of the present study was, therefore, to test whether or not the use of screw-retained all ceramic implant-borne reconstructions results in clinical, technical, and biologic outcomes similar to those obtained with cemented all ceramic reconstructions. The

hypothesis was that there is no difference in clinical, technical and biological parameters between the two types of retention.

MATERIALS AND METHODS

Study Design and Subjects

The study was designed as a parallel, single center randomized controlled clinical trial. All procedures and materials were approved by the local ethical committee (KEK-ZH-Nr.2010-0041), and all patients provided informed consent to participate. Forty-four patients in need of replacement of a single incisor, canine, or premolar were consecutively recruited at the Clinic of Fixed and Removable Prosthodontics and Dental Material Science, University of Zurich, Switzerland. Details on materials and methods were reported earlier.[12] In brief, all patients received a two-piece dental implant (OsseoSpeed, DENTSPLY Implants, Mölndal, Sweden) in the esthetic zone. They were then randomly assigned to a screw-retained (SR) or cemented reconstruction (CR), according to a computer-generated list. Allocation was concealed by using sealed envelopes, opened at the time of the final impression.

For all patients, customized CAD/CAM zirconia abutments (Atlantis, DENTSPLY Implants) were designed by the same experienced technician, following manufacturer's guidelines and milled in a centralized milling center. In group SR, the zirconia abutments (**Figure 1A**) were directly veneered (Creation ZI-F, Creation Willi Geller International GmbH). The final one-piece reconstructions were fixed with a torque of 20 Ncm onto the implants (**Figure 1B**); the screw access hole was then closed using a composite material.

In group CR, the dimension and position of the zirconia abutment shoulder was checked (**Figure 2A**) and, if necessary, the height was modified to position it circumferentially 1 mm submucosally. The abutments were screwed with a torque of 20 Ncm. After placing a retraction cord (Ultrapak, Ultradent Products GmbH Am Westhover Berg 30 51149 Köln), veneered lithium-disilicate crowns (e.max, e.max Ceram, Ivoclar Vivadent, Schaan, Liechtenstein) were cemented (**Figure 2B**) using a resin cement (Panavia 21, Kuraray Medical, Kuraray Europe GmbH BU Medical Products Philipp-Reis-Str. 4 65795 Hattersheim am Main Deutschland).

Clinical Examinations and Outcomes Measures

All patients were recalled for a baseline examination (BL; 1-3 weeks after crown insertion), at 6 months (FU-6M), 1 year (FU-1Y) as well as at 3 years (FU-3Y). For standardization purposes, two calibrated operators performed all examinations. At these visits, the following biological, technical and esthetic outcomes were assessed at the implant and control sites (contralateral tooth):

Biologic examinations

Periodontal parameters were assessed in millimeters at 6 sites around each implant / control tooth, including probing depth (PD), bleeding on probing (BOP), O'Leary's plaque control records (PCR), mucosal/ gingival recession (REC).

The width of keratinized mucosa (KM) was assessed at the mid-buccal aspect of the implant and the control tooth. The thickness of the buccal mucosa was measured to the nearest 0.5 mm at a level 1 mm below the gingival (control tooth) / mucosal (implant site) margin using an endodontic file. Peri-implant mucositis was defined as presence of BOP (>50 % of

sites) and peri-implantitis as bone loss of more than 2 mm combined with a positive BOP recording.[13]

Radiographic Examination

Standardized digital x-rays (Digora Optime, Soredex, Helsinki, Finland) were taken at implant sites using a paralleling technique with Rinn holders at the day of implant placement (IP), at the baseline examination and at all follow-up time-points up to 3 years. The marginal bone level was calculated at a 10 × to 15 × magnification using an open-source software (Image J; National Institutes of Health, Bethesda, MD, USA) by two operators after a calibration meeting. The distance between the implant shoulder and the bone crest was measured at the mesial and distal aspect of the implants to the nearest 0.1 mm (marginal bone level=MBL). The flat top of the implant shoulder and the pitch distance between two implant threads served as reference points for standardization purposes. In case of uncertainty, the x-rays were discussed between the examiners. Marginal bone level changes over time were then calculated between implant placement, baseline, 6 months, 1 year and 3 years.

Technical Examination

Technical aspects were evaluated at 6 months, 1 year and at 3 years according to modified USPHS (United States Public Health Service) criteria[14]. In brief, the reconstructions were examined for fracture of framework or of the veneering ceramic, occlusal roughness, loss of retention and under-/overcontouring. All parameters were rated alfa (A) in case of no problem, bravo (B) in case of minor extent of the complication, charlie (C) if the complication was major, and delta (D) if the reconstruction had to be removed due to the complication.

Soft tissue examinations

The mesial and distal papillae were evaluated using a papilla index (scores from 0 to 4)[15]

In addition, the height of the crown was assessed using a periodontal probe on the buccal crown surface to the nearest 0.5mm. In order to evaluate a possible mucosal/gingival recession or gain, the change of crown height over time was calculated (BL – FU).

Statistical analysis

All data were analyzed descriptively, calculating mean values, SDs, min, max and the quartiles. For the group comparisons, the Wilcoxon-Mann-Whitney test was applied for independent data or the Wilcoxon test for paired data for numerical variables. For the time effect analyses, parametric or nonparametric mixed model analyses were used. For the analyses of frequencies, the Fisher exact test was applied.

RESULTS

Forty-four patients (22 women, 22 men) were recruited between November 2011 and February 2014 and enrolled in the study. In total, 44 final reconstructions were inserted (20 CR and 24 SR). An overview on the locations is given in **Table 1**. Out of 44 enrolled subjects, 32 attended the FU-3Y (**Table A5)**. Four (9.1%) of the initially included patients were not available for the 3-year follow-up. Out of these, three (2 SR, 1 CR) patients could not be contacted despite numerous attempts. Another patient with a cemented reconstruction died 21 months after the baseline examination. Moreover, 8 patients (18.2%) lost the reconstruction due to technical (6 patients, 13.6%, 2 CR and 4 SR group) or biological complications (2 patients, 4.5%, only CR group). This resulted in 32 patients attending FU-3Y (**Figure 1C and 2C**). The mean age at this time point was 51.4 years (standard deviation 17.1)

Biologic outcomes

Clinical parameters

All data (PCR, BOP, PD, KM) are presented in **Tables A6 and A7**. Implants showed a higher mean probing depth (PD) than control teeth at 3 years. The median PD at implant sites was 3.0 mm (Q1:2.5; Q3:3.5) in the SR group and 3.0 mm (3.0; 4.0) in the CR group ($p=0.664$). Median changes in PD values from baseline to FU-3Y amounted to 0.5 mm (0.0; 1.0) (SR) and 0.5 mm (0.0; 1.0) (CR) (intragroup changes over time: $p=0.02$, $p=0.045$). BOP and PCR values did not reveal any significant differences between the groups at FU-3Y ($p=0.759$; $p=0.189$).

At FU-3Y, the median width of the buccal keratinized mucosa/gingiva was 3.0 mm (2.0; 4.0) at implants sites and 3.5 mm (3.0; 4.0) at control teeth in the SR group. The changes

from baseline to FU-3Y were not significant in both treatment groups. The median differences of the paired data between implants and control teeth amounted to -1.0 (-1.5; 0.0) (p=0.0078) (group SR). In the CR group, the median width was 3.0 mm (2.0; 4.0) at implant sites and 3.5 mm (2.5; 4.5) at control teeth. The median differences of the paired data were -0.25 (-1.0; 0.5) (p=0.4258).

The median thickness of the buccal soft tissue (**Table A8**) amounted to 2.3 mm (1.5; 2.5) at implants and 1.5 mm (1.0; 1.5) at control teeth in the SR group at 3 years. In the CR group, the corresponding median thickness was 2.5 mm (2.0; 3.0) at implant sites and 1.5 mm (1.0; 1.5) at control teeth. The medians between implants and teeth were not significantly different (p=0.743, p=0.550). From baseline to FU-3Y, the median change in soft tissue thickness in group SR was 0.5 (-0.5; 1) and in the CR group 0.25 (0.0; 1.0) (intragroup changes: p=0.271, p=0.271; intergroup changes of the medians: p=0.888).

Biological complications

In one patient, the implant with a cemented reconstruction was lost 9 months after baseline. Previously, no signs of a peri-implant disease were evident. The reason for the loss remained unknown. In a second case, the cemented crown had to be removed close to the 3-year follow-up due to cement excess and a subsequently established peri-implant disease. In addition, at FU-3Y, two implants showed signs of a peri-implant mucositis (6.2%): one in the CR group (7.1%), one in the SR group (5.6%).

Radiographic outcomes

The marginal bone level (MBL) at the different time-points are presented in **Table 2**.

At baseline, the median MBL was -0.4 mm (-0.7; -0.3) in the SR group and -0.5 mm (-0.6;-0.3) in the CR group (p=0.971). At FU-3Y, the mean MBL was -0.4 mm (-0.5; -0.3) in the SR group and -0.4 mm (-0.6;-0.3) in the CR group (p=0.864).

Technical outcomes

All data are presented in **Table 3.**

Six out of 44 (13.6%) initially enrolled patients lost the reconstructions due to a fracture of the zirconia abutment (four in group SR, two in group CR). In all these patients, new crowns were fabricated and inserted.

A common finding during the observation period was a slight occlusal roughness (surface diameter <2mm), reaching 50.0% of the examined reconstructions in the CR group and 18.2% in the SR group. A minor, polishable chipping was observed in one reconstruction in the CR group (5.6%). Loss of retention was observed at 6 crowns (all had an abutment fracture).

Overall major complications

Overall, cemented reconstructions (27.8 % of the CR crowns) showed more complications (biological: 16.7%, technical: 11.1%) than screw-retained reconstructions (22.7% of the SR crowns) (biological: 4.5%, technical 18.2%). The difference was not statistically significant (p=0.731).

For a detailed list of the major complications see **Table 4.**

Esthetic outcomes

Crown height / Mucosal and gingival level changes

Between BL and FU-3Y, the median change of the mucosal level was 0.0 mm (0.0; 1.0) at reconstructed implants in the SR group and 0.0 mm (0.0; 0.5) in the CR group. No significant differences were observed between the two groups ($p>0.440$) and compared to control teeth ($p>0.188$). (**Table A9**)

Modified Papilla Index

The modified papilla index revealed no significant differences between the two groups at 3 years ($p>0.319$) (**Table A10**).

DISCUSSION

The present RCT comparing cemented versus screw-retained zirconia-based single-tooth reconstructions predominantly revealed at 3 years: i) similar biological, technical and radiographic outcomes, ii) a high rate of catastrophic technical complications (15%) (SR>CR), iii) two major biological complications in the CR group only.

The overall survival rate of the inserted two-piece dental implants at 3 years was 97.5% (SR: 100%, CR 94.4%), which is in line with high survival rates reported in a recent systematic review (95.3% after 5 years)[3, 4]. Whereas at level of the implant the survival rates were high and only few biological complications occurred, at level of the reconstruction a high incidence of technical complications dropped the survival rate to 80.0% (SR: 81.8%, CR: 77.8%) at 3 years of function. Recent systematic reviews reported considerably higher survival rates for all-ceramic reconstructions (estimated 5-year survival rate of 93.0 to 97.6%)[3, 4]. A recent randomized clinical trial reported on zirconia abutments of the same type used as in the present investigation (Atlantis, DENTSPLY Implants). The 3-year success rate of zirconia-based reconstructions amounted to 82.2%, while reconstructions based on titanium or titanium nitride abutments had significantly higher success rates (both 100%). In contrast to the present investigation, in that study, implants in molar(s) sites were included, where higher loading forces can be expected[16].

In the present clinical trial, despite the differences of the implant- and reconstruction-based survival rates for CR and SR groups, no statistical significance was observed. Biological outcomes, like PCR, BOP, PD, KM and mucosal thickness as well as technical parameters (USPHS parameters) and marginal bone levels were similar in both groups. In terms of marginal bone levels, two recent systematic reviews indicated less marginal bone loss for cemented reconstructions[6, 17], which is in contrast to the present study. However, both

reviews included different connection types and abutment materials, which seem to be related to marginal bone loss (>2mm)[6]. In the present study, two-piece dental implants with non-matching implant-abutment junctions were used. After an initial remodeling in the period between implant placement and loading, stable marginal bone levels during the 3 years of follow-up were observed. This is consistent with previously reported clinical studies reporting statistically significant mean marginal bone level changes between implant placement and loading, but stability during the follow-up[18, 19].

Biological complications were observed in 10.0% (SR: 4.5%, CR: 16.7%) of the reconstructions, while technical complications occurred in 15.0% (SR: 18.2%, CR: 11.1%) of the cases. In general, cemented reconstructions showed slightly more biological complications, while screw-retained were associated with slightly more technical complications. This observation is in line with systematic reviews focusing on implant-borne reconstructions[1, 6, 11]. Cemented reconstructions showed more serious biological complications (implant loss, bone loss >2 mm), while screw-retained reconstructions had more technical complications. Nevertheless, fewer biological and technical complications were observed for screw-retained reconstructions.

In the present study, the low survival rate after 3 years of function was attributed to the high number of catastrophic technical complications. Out of 8 lost reconstructions, 6 were fractures of the zirconia framework and consequently resulted in a loss of retention. In a systematic review including abutments with different materials and a mean follow-up of at least 3 years, zirconia abutments performed favorably, presenting only a single fracture, out of a pool of 124 single implant abutments. No statistically significant differences were observed in terms of the technical complication rates for ceramic and metal abutments[20]. This is supported by two longer-term studies, where out of 31 and out of 30 zirconia

abutments, no fractures were observed during the entire follow-up time of 10- to 11-years [21, 22]. Like in the majority of studies on zirconia abutments available, the reconstructions were inserted on implants with external connections. One might speculate that the high fracture rate in the present study is associated with the internal connection. Based on in vitro studies, a less predictable behavior and lower bending moments of internally compared to externally connected zirconia abutments were observed [23-26]. In contrast, clinical information from a systematic review showed no statistically significant difference in the fracture rate between ceramic abutments with internal and external connection designs (5-year complication summary estimate: 1.9% for internal and 2.0% for external connections). However, fractures of ceramic abutments were significantly more frequent than of metal abutments (cumulative 5-year complication rate: 0.08% versus 1.8%)[6]. Further clinical data from a retrospective study including 965 zirconia abutments with a mean follow-up time of 6 years, showed the highest fracture incidence (6.9%) with internal full-zirconia connection, compared to external connection and internal connection with metal components. The authors suspected that friction stress, generated by fixation screws or overpreparation, and thinning of the lateral walls of abutments could be the critical factors for the high number of fractured internally connected full-zirconia abutments[27].

Another explanation for the high fracture rate in the current study could be the implant site, due to the fact that 4 out of 6 fractured abutments were located in premolar areas. This is supported by a randomized clinical trial including the same abutment type as in the present investigation reporting a high number of fractures in particular in posterior areas (4 out of 5 fractures). The authors therefore recommended to use zirconia abutments only in the anterior area[16]. However, in contrast to the present study, they included molar sites as well. Further, it has to be considered that in the current investigation the vast majority of

the implants (75%) were placed in the premolar area, leaving room for a speculation that the high fracture rate could be linked to the implant site.

Data from a recently published study on 20 patients with one-piece zirconia abutments on internally connected two-piece dental implants similar to the present study reported a survival rate on the restorative level of 94.1 % at 5 years, which is in contrast to the high fracture rate in the current study. Implant sites were in 10 cases in the anterior (incisors), while 10 implants were placed in premolar sites. Overall, only a single abutment fractured (premolar site). The main difference to the current study population is that all crowns were cemented[28]. Due to the fact that in the present study screw-retained reconstructions showed a tendency to be more prone to fracture, compared to cemented reconstructions, one may speculate on the reason for that tendency. An explanation could be the ability of cemented crowns to slightly compensate the tension caused by a too strong contact point during cementation, due to the cementation gap.

In terms of biological complications, no statistical difference between the groups was observed. Two complications in the CR group were of catastrophic origin, though. At least one of the two cases was found to be related to cement excess and a subsequent development of a peri-implant disease with continuous bone loss.

There is some evidence that catastrophic failures of cemented reconstructions are often associated with cement excess[29]. The difficult removal of these remnants, even for experienced clinicians[30], has been associated with the development of peri-implant diseases, predominantly with deep submucosal crown margins[31, 32]. In the present study, the abutment margin was placed at most 1 mm submucosally. A recent *in vitro* study recommended an epimucosal crown-abutment interface in oral as well as interdental regions, and not to exceed 1.5 mm submucosally in buccal regions. The investigation also

showed that concave emergence profiles increased the risk for cement remnants on the abutment surface[33]. A mismatch between the conditioned soft tissues (emergence profile) and the concave abutment design thereby results in a higher incidence of cement excess.

The limited number of patients (44) and a drop-out rate of 9.1% can be considered as limitations of the present study. Moreover, the number of restored implants in posterior premolar sites (33) was higher than in the anterior area (11). This unbalanced distribution could potentially represent a confounding factor for technical outcome measures. Another limitation is related to the design of the two types of retention. In the screw-retained group, the abutments were directly veneered, whereas cemented reconstructions encompassed a lithium-disilicate crown. Despite these differences that could potentially influence technical outcomes, in particular fracture of the veneering ceramic, the chipping rate was low and not statistically significant different between the groups.

CONCLUSIONS

During 3 years of function, cemented and screw-retained zirconia-based single-tooth reconstructions on two-piece implants showed similar survival rates, as well as biological, technical and radiographic outcomes. However, the incidence of catastrophic technical complications was high for these one-piece zirconia abutments on internally connected two-piece dental implants. In particular a high number of abutment fractures was observed. Catastrophic biological complications occurred in the CR group only. One of the two cases presented a clear association with undetected cement remnants.

Acknowledgements and conflict of interest

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FIGURES:

Figure 1: A) Try-in of a zirconia abutment before direct veneering (site: 22). All ceramic implant-borne screw-retained reconstruction at baseline (B) and at 3-year follow-up (C).

Figure 2: A) Try-in of a zirconia abutment for a cemented reconstruction (site: 24). All ceramic implant-borne cemented reconstruction at baseline (B) and at 3-year follow-up (C).

TABLES:

Table 1: Implant sites (SR: screw-retained reconstruction, CR: cemented reconstruction)

Table 2: Marginal bone levels (MBL, in mm) at different time points (BL: baseline, FU-6M: 6-month follow-up, FU-1Y: 1-year follow-up, FU-3Y: 3-year follow-up)

Table 3: USPHS criteria in percent (and number of reconstructions) during the 3 years of follow-up, including all crowns (40 patients): 18 cemented reconstructions (CR) and 22 screw-retained reconstructions (SR)

Table 4: Major complications per subject and time point after baseline (BL). CR= cemented reconstructions, SR= screw-retained reconstructions.

Appendix:

Table A5: Subjects during 3-years of follow-up

Table A6: Plaque control record (PCR) and bleeding on probing (BoP) at screw-retained resp. cemented reconstructions, as well as at contralateral control teeth, at 3-year follow-up.

Table A7: Probing depth (PD), width of keratinized mucosa (KM) at screw-retained resp. cemented reconstructions, as well as at contralateral control teeth, at baseline (BL) and 3-year follow-up (FU-3Y).

Table A8: Soft tissue thickness 1mm apical of gingival margin (in mm) at different time points (BL: baseline, FU-6M: 6-month follow-up, FU-1Y: 1-year follow-up, FU-3Y: 3-year follow-up)

Table A9: Mucosal/gingival level change between baseline (BL) and 6-month follow-up (6M), 1-year follow-up (1Y) and 3-year follow-up (3Y), respectively.

Table A10: Modified Papilla Index (MPI, according to Jemt) at different time points (BL: baseline, FU-6M: 6-month follow-up, FU-1Y: 1-year follow-up, FU-3Y: 3-year follow-up)

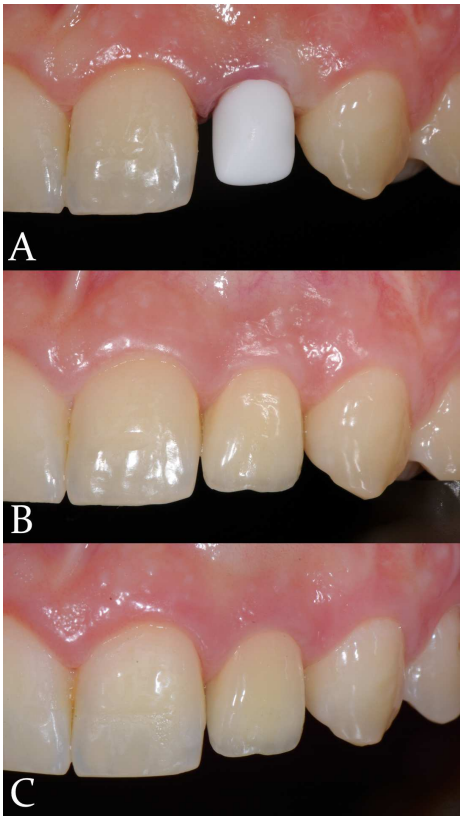

Figure 1

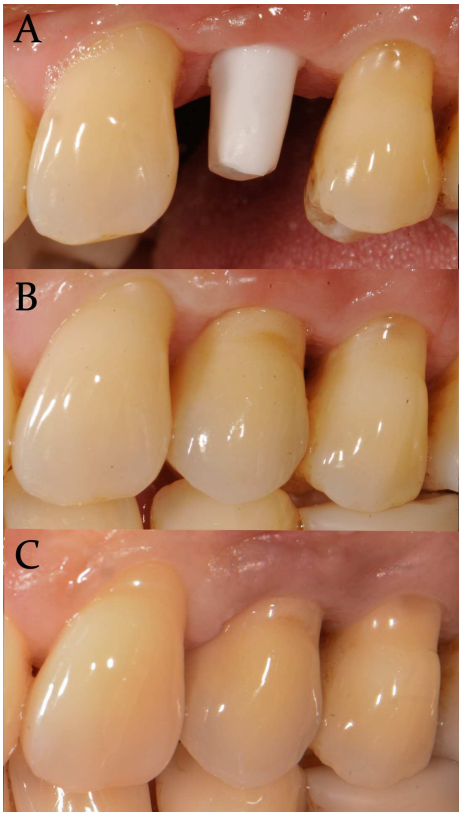

Figure 2

Table 1: Implant sites (SR: screw-retained reconstruction, CR: cemented reconstruction)

Site	Upper jaw	Lower jaw	Total
central incisor	5 (2 SR; 3 CR)	0	5 (2 SR; 3 CR)
lateral incisor	5 (4 SR; 1 CR)	0	5 (4 SR; 1 CR)
canine	0	1 (SR)	1 (SR)
first premolar	12 (5 SR; 7 CR)	1 (SR)	13 (6 SR; 7 CR)
second premolar	12 (7 SR; 5 CR)	8 (4 SR; 4 CR)	20 (11 SR; 9 CR)
Total	**34 (18 SR; 16 CR)**	**10 (6 SR; 4 CR)**	**44 (24 SR; 20 CR)**

Table 2: Marginal bone levels (MBL, in mm) at different time points (BL: baseline, FU-6M: 6-month follow-up, FU-1Y: 1-year follow-up, FU-3Y: 3-year follow-up)

	BL	FU-6M	FU-1Y	FU-3Y
screw-retained reconstructions (SR)				
Mean / Standard deviation	-0.5±0.3	-0.4±0.3	-0.6±0.2	-0.5±0.3
Median	-0.4	-0.5	-0.5	-0.4
1st quantile (Q1)	-0.7	-0.6	-0.8	-0.5
3rd quantile (Q3)	-0.3	-0.2	-0.4	-0.3
cemented reconstructions (CR)				
Mean / Standard deviation	-0.5±0.4	-0.7±0.4	-0.6±0.5	-0.5±0.2
Median	-0.5	-0.5	-0.5	-0.4
1st quantile (Q1)	-0.6	-0.8	-0.6	-0.6
3rd quantile (Q3)	-0.3	-0.4	-0.4	-0.3

Table 3: USPHS criteria in percent (and number of reconstructions) during the 3 years of follow-up, including all crowns (40 patients): 18 cemented reconstructions (CR) and 22 screw-retained reconstructions (SR)

		Alfa (A)	Bravo (B)	Charlie (C)	Delta (D)
		No fracture			Fracture = loss of reconstruction
Fracture of framework	SR	81.8 (18)	-	-	18.2 (4)
	CR	88.9 (16)	-	-	11.1 (2)
		No fracture	Minor chipping, polishable	Major chipping, up to framework	Fracture = loss of reconstruction
Fracture of veneering ceramic	SR	100.0 (22)	0.0	0.0	0.0
	CR	94.4 (17)	5.6 (1)	0.0	0.0
		No roughness	Slight roughness, ø<2mm	Obvious roughness, ø>2mm	Reconstruction needs to be replaced
Occlusal roughness	SR	81.8 (18)	18.2(4)	0.0	0.0
	CR	50.0 (9)	50.0 (9)	0.0	0.0
		No loss of retention	Crown (decementation)	Abutment (loosening)	Abutment (fracture)
Loss of retention	SR	81.8 (18)	Not applicable	0.0	18.2 (4)
	CR	88.9 (16)	0.0	0.0	11.1 (2)
		Perfectly contoured	Slightly under-/overcontoured	Pronounced under-/overcontoured	Reconstruction inacceptable
Contour of reconstruction	SR	100.0 (22)	0.0	0.0	0.0
	CR	94.4 (17)	5.6 (1)	0.0	0.0

Table 4: Major complications per subject and time point after baseline (BL). CR= cemented reconstructions, SR= screw-retained reconstructions.

Subject Nr	Group	Site	Implant diameter	Complication	Time point after BL (in months)
7	SR	24	4 mm	Abutment fracture	33
10	CR	21	4 mm	Abutment fracture	9
13	CR	14	4 mm	Crown removal to treat a peri-implantitis	35
15	SR	15	4 mm	Abutment fracture	2
17	CR	15	3.5 mm	Implant loss	9
22	SR	14	4 mm	Abutment fracture	31
23	CR	45	4 mm	Abutment fracture	24
29	SR	33	3.5 mm	Abutment fracture	14
Total				**8 complications**	**19.6±12.7**