Cemented CeraOne® and Porcelain Fused to TiAdapt™ Abutment Single-Implant Crown Restorations: A 10-Year Comparative Follow-Up Study

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ABSTRACT

Background: Long-term data comparing cemented and noncemented single-implant restorations has not been reported.

Aim: To compare clinical and radiographic performance of single-implant crown restorations made by either directly baked porcelain to custom-made TiAdapt™ titanium abutments (Nobel Biocare AB, Göteborg, Sweden) (test) or cement crowns onto CeraOne® (Nobel Biocare AB) abutments (control) after 10 years in function.

Materials and Methods: Altogether, 35 consecutive patients were provided with 41 turned single Brånemark System® implants (Nobel Biocare AB) in the partially edentulous upper jaw. By random, 15 and 20 patients were provided with 18 test and 23 control implant crowns, respectively. Thereafter, clinical and radiographic data were collected and compared between the two groups.

Results: None of the implants were found loose during the follow-up period (100%). Few clinical problems were observed, and the overall average marginal bone loss was 0.26 mm (SD 0.64) during 10 years in function. After the final tightening of the crowns, no significant differences were observed between the test and control groups ($p > .05$). The head of the implants was placed on an average 6.3 mm (SD 2.24) below the cement/enamel junction of the adjacent teeth (range 2.5–10.0 mm). Implants with reported mechanical and/or mucosal problems or placed more apically in relation to the adjacent teeth did not present more bone loss as compared with implants with no problems or placed more coronally, respectively ($p > .05$).

Conclusions: There seems to be no obvious clinical or radiographic differences between the test and control single-implant restorations during 10 years of follow-up. Occasionally, some restorations presented loose abutment screws and/or fistulas during follow-up. This implies a certain need for maintenance where a one-piece single-implant protocol (test) allows both for a simple clinical procedure at placement without cementation problems, as well as for an easy and simple maintenance of installed single implant crowns in long-term function.

KEY WORDS: bone loss, cementation, complications, fistula, single implants

INTRODUCTION

The original Brånemark single-implant technique was designed as a one-piece abutment crown restoration using a titanium abutment to which resin veneer materials were cured.[1] As resin veneers were not an optimal aesthetic solution, this approach was early replaced by a two-piece restoration protocol, where separate porcelain fused to metal crowns were cemented to titanium abutments.[1–3] This approach evolved gradually to the design of the standardized CeraOne® (Nobel Biocare AB, Göteborg, Sweden) single-implant technique with cemented crowns to premachined titanium abutments.[4]

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As a complement to this technique, a more customized single-implant technique was also introduced,[5–8] allowing for the preparation of the titanium abutment cylinder and thereby allowing for a more individual placement of the crown margin in relation to the mucosa. This alternative technique could be used with separate crowns, cemented to the abutments, or as a one-piece restoration, where the veneering porcelain was baked directly onto the abutment and thereafter screwed to the implant through an access hole.[8]

As compared with the dentate situation with periodontal gingival attachment to the tooth abutment, the implant system lacks similar attachment to the abutment, leaving the marginal bone more unprotected.[9] Thus, the risk of introducing cement remnants deeper down in the tissue is obvious in cemented implant situations. This problem with cementation has been addressed by Wannfors and Smedberg,[10] suggesting more bone loss at single implants with wider cement margins. As cementation is a potential problem in implant dentistry, it could be expected that one-piece single-implant restorations present a better biologic situation than cemented, two-piece restorations. However, short-term data indicate similar biologic response for the two alternatives,[11] but long-term data are not available at the present time for comparisons.

The aim of the present follow-up study was to compare the long-term performance of two different single-implant crown techniques, using either cemented porcelain fused to metal crowns or one-piece restoration with porcelain fused directly onto the customized titanium abutment.

MATERIALS AND METHODS

The present study was designed as a retrospective study, covering consecutive patients provided with two designs of single-implant crown restorations in the upper jaw, randomly distributed between the patients. Altogether, 35 patients provided with 41 single-implant restorations were included in the present study. During the inclusion period, 15 of the patients were treated with one-piece crown restorations (test), using porcelain veneers baked directly on custom-made TiAdapt™ titanium abutments (Nobel Biocare AB).[8] The remaining 20 patients (control) were treated with single implant crowns cemented to CeraOne single-implant abutments.[4]

Test Group – One-Piece TiAdapt Group

The test group comprised of 15 by random consecutively treated patients, where 11 patients were males. Mean age at first surgery was 29.2 years (SD 14.2 years), and age ranged between 18 and 72 years (Table 1). The patients received altogether 18 single-crown restorations in the upper jaw. Seven crowns were central incisors, eight were lateral incisors, two were bicuspids, and one crown was a canine, respectively. No health problems were reported at the first surgery, and no patient was smoking.

The patients were treated with 18 turned Brånemark implants and standard abutments (Nobel Biocare AB), according to routine two-stage surgical procedures presented elsewhere.[3,8,12] After mucosal healing, a final impression was made directly onto the implant head.[8] Thereafter, a premachined titanium abutment was selected (TiAdapt), which the technician contoured manually.[8] A chamfer was placed following the mucosal contour about 1 to 2 mm below the mucosal margin (Figure 1). After the completion of the abutment, low fusing porcelain (Procera®, Nobel Biocare AB) was baked directly to the abutment cylinder (Figure 2). The final crown was provided with an access hole on the palatal/occlusal surface.

The crown restoration was manually secured to the implant by means of a CeraOne abutment screw, followed by temporary sealing of the access hole with gutta-percha. Final tightening was performed about 1

TABLE 1 Number of Patients and Single-Implant Crown Restorations in the Upper Jaw, and Mean Age of Test (TiAdapt) and Control (CeraOne) Groups at the Time of Implant Surgery

	Patients/Implants in the TiAdapt Group			Patients/Implants in the CeraOne Group			
	Number	Mean Age	SD (years)	Number	Mean Age	SD (years)	Total Number
Males	11/13	27.3	8.6	14/15	33.3	13.2	25/28
Females	4/5	34.5	25.3	6/8	36.3	21.0	10/13
Total	15/18	29.2	14.1	20/23	33.5	15.6	35/41

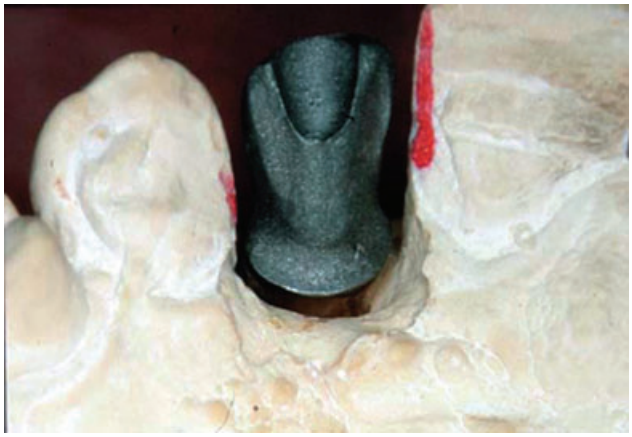

Figure 1 Customized TiAdapt single-tooth titanium implant abutment.

month after insertion, followed by sealing the access hole with composite resin. Intraoral apical radiographs were taken at abutment surgery and at the final tightening of the crown. Thereafter, the patients were encouraged to contact the clinic whenever they had any problems with their implant restorations. Routine examinations with intraoral apical radiographs were scheduled after 1, 5, and 10 years in function.

Control Group – Cemented CeraOne Group

The control group comprised of 20 consecutively treated patients, where 14 patients were males (see Table 1). Mean age at first surgery was 33.5 years (SD 15.56), and age ranged between 18 and 75 years. The patients received altogether 23 single-crown restorations. Ten crowns were central incisors, nine were lateral incisors, and two crowns were placed in the canine and in the bicuspid area, respectively. No health problems were reported at the first surgery, and no patient was smoking.

Figure 2 Final TiAdapt single-implant restoration with CeraOne abutment screw.

Surgical procedure was the same for the control group[12] as earlier presented for the test group. After the final impression and fabrication of the master cast, a CeraOne abutment was selected.[4] Length of the abutment cylinder was selected to allow the crown-abutment margin to be placed 1 to 2 mm below the mucosal margin at the buccal aspect of the restoration. All but three crowns were cemented to the abutments outside the mouth, followed by manually securing the crown-abutment restoration to the implant through an access hole, placed on the palatal/occlusal surface. The follow-up protocol was similar for the cemented, control group as compared to the noncemented test group after the placement of the restorations.

Data were retrieved from the patients' files, also including all problems encountered during the follow-up period. Vertical distance between the fixture/abutment junction (FAJ) of the single implant in relation to the cement/enamel junction (CEJ) of the adjacent tooth on the mesial side was measured.[13] The marginal bone level at the implants was measured to the closest 0.3 mm on the mesial and distal sides of the implant. A mean value between the mesial and distal sides was used for each implant. The reference for these measurements was the FAJ, placed 0.8 mm coronal of the implant reference point used in the previous studies.[8,14] *t*-Test for unpaired samples was used to assess differences between groups. Significance was set to 5% ($p < .05$).

RESULTS

Five and six of included patients provided with one TiAdapt or CeraOne crown each were lost to follow-up during the 10-year inclusion period, respectively. Four of these patients were lost before the 5-year examination, and another four patients were lost just after the 5-year examination. The remaining three patients were lost after 6 to 8 years of follow-up. Patients were lost after they had moved from the city ($n = 5$), had examinations at their ordinary dentists only ($n = 4$), had their crown replaced ($n = 1$), or were deceased ($n = 1$).

All implants remained integrated during the time of follow-up. One of the crowns was replaced after trauma,

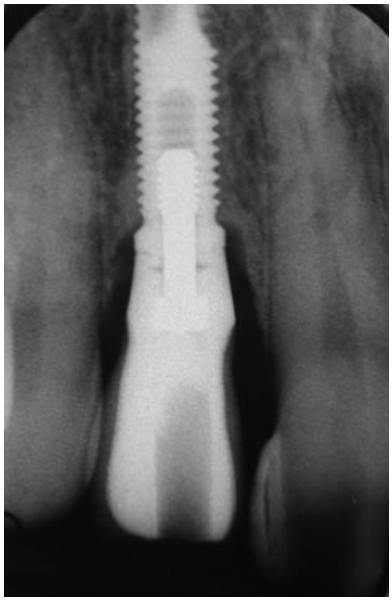

Figure 3 Right lateral incisor TiAdapt single-implant restoration after 10 years in function. Implant head is placed 10 mm below the cement/enamel junction of the central incisor.

and thereafter the patient was withdrawn from follow-up, as accounted for above.

Eleven and 15 of the test and control restorations were followed up without any reported clinical problems (63%), respectively. Loose abutment screws were observed in altogether five crown restorations, two in the test and three in the control groups, respectively. These problems occurred for the first time during the first year ($n = 1$), second year ($n = 1$), third year ($n = 1$), and sixth year ($n = 2$) of function. Two of these crown restorations presented both loose abutment screws a second time during the ninth year of function. Buccal fistulas and/or pus were observed during the entire follow-up period at two tests and two control crowns, respectively. Vertical and/or buccal mucosal recession was noted at two crowns, one in each group.

Vertical distance between the implant head (FAJ) and the CEJ of the adjacent tooth ranged from 2.5 to 10.0 mm (Figure 3), with a mean distance of 6.5 mm (SD 2.24) and 6.5 mm (1.26) for the test and control crowns, respectively. Altogether, three of the implants were placed 4 mm or less below CEJ, 15 and 13 implants from 4.5 to 6 mm, and 6.5 to 8 mm below CEJ, respectively. The remaining eight implants were placed more than 8 mm below CEJ.

Mean time between radiographs at abutment connection surgery and final tightening of the TiAdapt and CeraOne crowns was 111.1 days (SD 47.28) and 71.6 days (SD 31.03), respectively ($p < .01$).

Fourteen of the cemented crowns in the control group showed optimal fit to the abutment cylinder, without any radiographic signs of gaps between crowns and abutment shoulders. Out of the remaining nine restorations, eight presented small marginal cement gaps (Figure 4), and one with a more obvious marginal gap. Two restorations had cement remnants in the tissue that were removed in connection to the radiographic examination at the final tightening. No significant differences with regard to marginal bone loss were observed between implants presenting no gaps and implants with marginal gaps during follow-up ($p > .05$).

Mean marginal bone levels and mean marginal bone loss at the single-implant restorations are presented in Tables 2 and 3. From Table 2, it can be observed that the distances from FAJ to the marginal bone level progressively increases by time in both the test and control groups, but no statistical difference can be observed between the groups ($p > .05$).

Bone loss was most pronounced during the first year of follow-up, followed by very small average as well as individual changes of marginal bone loss during the following years (see Table 3). Overall, mean marginal bone loss was 0.26 mm (SD 0.64) during 10 years of function. Significantly more bone was lost ($p < .01$) at implants from the abutment connection surgery to final tightening in the control group (see Table 3). However, bone loss from the second surgery on the first annual

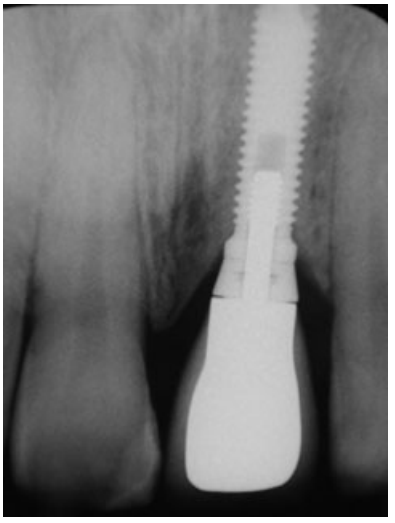

Figure 4 Left central incisor cemented CeraOne single-implant restoration after 1 year in function. Notice the small gap between the crown and abutment cylinder.

TABLE 2 Marginal Bone Levels at Implants in the Test (TiAdapt) and Control (CeraOne) Groups during Follow-Up

	Bone Levels during Follow-Up in Millimeter				
	Abutment	Placement	1 Year	5 Years	10 Years
TiAdapt					
Implants (*n*)	17	15	16	16	11
Mean	0.83	1.12	1.38	1.34	1.67
SD	0.10	0.33	0.42	0.57	0.57
Range	0.8–1.2	0.8–1.8	0.8–2.1	0.8–2.2	0.8–2.4
>2.5 mm (*n*)	0	0	0	0	0
CeraOne					
Implants (*n*)	23	18	19	19	17
Mean	0.88	1.40	1.48	1.49	1.56
SD	0.29	0.55	0.51	0.58	0.71
Range	0.8–2.2	0.8–2.7	0.8–2.4	0.8–2.8	0.8–2.7
>2.5 mm (*n*)	0	1	0	1	2

Number of implants (*n*) with bone levels below the second thread (>2.5 mm) of the implant is also given for the two groups.
Bone level is measured from the fixture/abutment junction.

TABLE 3 Marginal Bone Loss at Implants in the Test (TiAdapt) and Control (CeraOne) Groups during Follow-Up from Abutment Connection Surgery (Abut.) to 10th Year of Follow-up

	Bone Loss during Follow-Up					
	Abut.–0	0–1 Year	0–5 Years	0–10 Years	1–5 Years	1–10 Years
TiAdapt						
Implants	14	14	13	11	15	11
Mean	0.28*	0.24	0.27	0.36	0.03	0.29
SD	0.32	0.37	0.57	0.74	0.55	0.41
Range	–0.2 to 0.8	–0.4 to 0.9	–1.0 to 1.1	–0.8 to 1.3	–1.1 to 1.0	–0.7 to 0.8
	Number (%) of Implants					
≤0 mm	5 (36)	6 (43)	7 (54)	4 (36)	9 (60)	3 (27)
>2.0 mm	0	0	0	0	0	0
CeraOne						
Implants	17	13	15	13	15	17
Mean	0.61*	0.12	0.07	0.18	–0.01	0.14
SD	0.51	0.46	0.52	0.57	0.49	0.64
Range	0.2–1.7	–0.8 to 0.9	–1.1 to 0.8	–1.1 to 1.1	–1.1 to 0.8	–1.1 to 1.1
	Number (%) of Implants					
≤0 mm	4 (36)	8 (62)	9 (60)	7 (54)	9 (60)	8 (47)
>2.0 mm	0	0	0	0	0	0

*Significant difference ($p < .01$).

checkup was 0.55 mm (SD 0.44) and 0.58 mm (SD 0.44) for the test and control groups ($p > .05$), respectively. After the final tightening, no further significant differences in bone loss were observed between the groups ($p > .05$).

With regard to the distance between FAJ and CEJ, implants with the shortest distance ($Min^{50\%}$ implants, $n = 20$) showed an average bone loss of 0.64 mm (SD 0.44) from the abutment connection surgery on the first annual checkup. The group of implants with the longest distance ($Max^{50\%}$ implants, $n = 21$) presented an average bone loss of 0.50 mm (SD 0.37) during the same period of time ($p > .05$). Thereafter, only insignificant differences ($p > .05$) in mean marginal bone loss were found during the following years between the two groups.

Mean marginal bone loss for implants with mechanical/fistula or mucosal recession problems ($n = 8$) and implants with no problems ($n = 20$) was 0.38 mm (SD 0.47) and 0.08 mm (SD 0.56) during the first 5 years in function, respectively ($p > .05$). The corresponding bone loss during 10 years in function was 0.30 mm (SD 0.67) and 0.25 mm (SD 0.65) for problem ($n = 8$) and no problem ($n = 17$) implants, respectively ($p > .05$).

DISCUSSION

Within the limitation of the relatively small numbers of patients, the present data indicate similar survival of implants and comparable clinical and radiographic response over a 10-year period of time, irrespective of whether cemented or one-piece implant-crown restorations were used. The favorable results are in accordance with other medium- to long-term studies on single-implant treatment.[13,15–21]

In comparison to the screw-retained implant restorations, Weber and colleagues[22] reported more mucosal problems at implants supporting cemented restorations. In the present study, higher levels of average bone loss were observed for cemented control restorations before the final tightening (see Table 3), supporting the observations made by Weber and colleagues.[22] As a shorter average time period ($p < .01$) from the second surgery radiographs to the final tightening examination radiographs for the cemented control group would be expected to result in lower levels of bone loss, the observed difference of the significantly higher levels of bone loss for this group is further strengthened. Accordingly, it can be assumed that the clinical manipulation with cementation of the crowns, even outside the mouth, induces an early bone resorption at the implants. However, it can also be noticed that differences in bone levels between the groups are leveling out by time, already seen at the first annual checkup (see Tables 2 and 3). This indicates that what was measured as early vertical bone loss possibly could have been a result of decreased bone density that is thereafter increased by time, when a more steady-state situation is achieved. Similar situations have been observed when single abutment screws have been loose for longer time periods and where bone levels are reestablished after retightening (Figure 5, A–C). Accordingly, differences in single-implant crown techniques may be reflected in early differences in bone response, but becomes insignificant in longer time perspectives.

In contrast to the present findings, Wannfors and Smedberg[10] reported that more marginal bone loss was observed in situations with wider cement margins at cemented single-implant crown restorations. The reason for lack of consistency in bone response between the present data and Wannfors and Smedberg[10] study is difficult to explain. However, it could be speculated that more crowns generally presented wider margins in their study, or that possibly, implants were placed more coronally as compared with the present implants. If implants were placed deeper in the present study as compared with Wannfors and Smedberg,[10] it could be assumed that longer abutment cylinders would place the cement margins further away from the bone as compared with more coronally placed implants with shorter distance between the cement margin and the bone.

Both clinical protocols for the test and control patients involved the removal of the original healing abutment several times during fabrication of the single-crown restoration. This procedure may introduce concern for marginal bone loss at the implants, based on the observations by Abrahamsson and colleagues.[23] They showed, in an animal study, significantly more marginal bone loss at implants where abutments had been repeatedly dis- and reconnected compared with implants where the abutments had been left undisturbed.[24] However, in accordance with an earlier study,[13] such a concern cannot be verified in the present clinical material with average levels of bone loss of 0.6 mm from the abutment connection surgery to the first annual examination in both groups, well below the acceptable levels of bone loss for successful implants.[24]

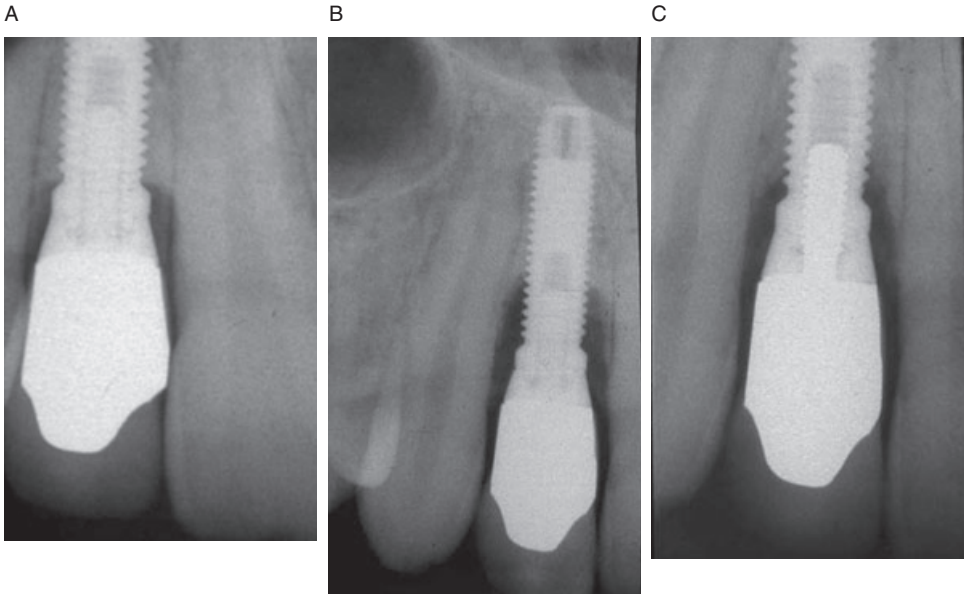

Figure 5 *A*, Right lateral incisor implant in a male patient after 6 years in function. Notice the stable bone level above the first implant thread and abutment screw in titanium. *B*, Right lateral incisor implant in a male patient after 9 years in function with bone loss after about 6 months function with a clinically loose abutment screw. After the replacement with a new Au abutment screw, the crown restoration is retightened. *C*, Right lateral incisor implant in a male patient after 10 years in function. Notice the regain of bone and the new abutment screw in gold alloy.

In accordance to another recently published study on early single-implant restorations,[13] the present patients were restored without considering local bone augmentation prior to implant surgery. As these patients were restored before local bone augmentation techniques had evolved in implant dentistry, the present implants have been placed deep up into the crest. Also, in accordance to this earlier study,[13] it can be noticed that the level of placement of the implant head in relation to the adjacent teeth is of no significant importance in relation to marginal bone loss. Thus, it can be argued both for coronal placement of implant heads, reducing the mucosal thickness down to the bone, as well as for deep placement of the implant head. A more coronal placement of the implant could possibly be associated with lower prevalence of "peri-implantitis" with less deep "pockets" at the implants, as reported by Roos-Jansåker and colleagues[25] and Fransson and colleagues,[26] which was shown, however, not on a patient but on an implant level. On the other hand, deeper placement of the implants could possibly provide a longer "safety" distance down to the marginal bone, as discussed previously. This "safety" distance could also apply for the low prevalence of marginal bone loss in situations with loose screws and buccal fistulas, as also reported in the previous study.[13] Some few situations with screw loosening could be found in the later stage of function in the present study. This may indicate that the incidence of screw loosening may, to some extent, be a time-dependent problem. If so, a clinical protocol with easy access to the abutment screws may be favorable, as performed here. Accordingly, a one-piece single-implant protocol would allow not only for a simple clinical procedure at placement without cementation problems, but also for an easy and simple maintenance of the installed single implant crown, as suggested by others.[27]

CONCLUSIONS

Besides early differences in bone response, there seems to be no obvious clinical or radiographic differences between the test and control single-implant restorations during 10 years of follow-up. Deep placement of implant heads could be considered as a risk factor with potentially deep probing depths at the implants. However, bone resorption was similar for apically placed as compared with coronally placed implants, and it could be argued that apically placed implants could be provided with a "safety" distance, protecting the bone from possibly unfavorable cement margins. Some few loose abutment screws in the later stages indicate a time-dependent mechanical pattern. This implies that a one-piece single-implant protocol (test) allows both for a

simple clinical procedure at placement without cementation problems as well as for an easy and simple maintenance of installed single implant crowns in long-term function.

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