Acta Odontologica Scandinavica. 2015; 73: 461–466

informa healthcare

ORIGINAL ARTICLE

Consecutive unsplinted implant-supported restorations to replace lost multiple adjacent posterior teeth: A 4-year prospective cohort study

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Abstract

Objective. The aim of this study was to investigate the various events occurring in unsplinted implant restoration in posterior jaws during a period of 4 years. ***Materials and methods.*** From August 2008 to April 2009, eight volunteers (three men and five women) who had two or more consecutively missing teeth received 20 implants in posterior maxillae and mandibles. Unsplinted single crowns were delivered to each implant. For the 4-year follow-up periods, patients were enrolled in a maintenance schedule at 1, 3, 6, 12, 24, 36 and 48 months. The data, including a questionnaire, radiography, mobility and probing were recorded on regular check-ups. ***Results.*** A total of 20 implants in eight patients were followed up for 48 months, showing a 100% survival rate. Mean marginal bone loss around implants was 0.26 mm. Statistical analysis revealed insignificant correlation between metal-ceramic and zirconia-ceramic crowns and among implant lengths (8.5 mm, 10 mm and 11.5 mm). Mean probing depths were similar or insignificantly different, regardless of the materials used or length of implants. The most frequent complications, in decreasing order, were food impaction (65%) and porcelain chipping (45%), sensitivity (25%), pain (20%) and loose contact (15%). Compared with metal-ceramic crowns, zirconia-ceramic crowns showed more unfavorable cases of porcelain chipping ($p = 0.017$), pain ($p = 0.007$) and loose contact with an adjacent crown ($p = 0.031$). ***Conclusions.*** Within the limits of the sample size, this study showed that unsplinted implant-supported single restorations to replace consecutive posterior missing teeth may function well.

Key Words: *dental prosthesis design, prospective studies, single-tooth dental implants*

Introduction

When two or more dental implants are adjacently placed to one another for replacing the multiple missing teeth, the dental prosthesis splinting the implants is known to be a principle for restoration, which effectively distributes mastication forces [1]. However, separate single implant-supported crowns for the restoration of the lost adjacent multiple teeth are considered to be closer to natural dentition and to be more capable of achieving a passive framework fit [2]. The clinical study on this restorative modality is important because it can give a dental clinician a simple treatment method. For example, when a patient loses the right maxillary first premolar after single implant-supported crown restoration for the missing right maxillary second premolar, the patient can be simply treated with another single implant-supported crown without the removal of the second premolar single restoration for splinting.

A previous study [3] reported that the multiple single restorations with the unsplinted implants yielded good implant survival and a small amount of marginal bone resorption. However, investigations

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(Received 28 July 2014; accepted 25 October 2014)

ISSN 0001-6357 print/ISSN 1502-3850 online © 2015 Informa Healthcare
DOI: 10.3109/00016357.2014.983543

on the long-term clinical outcomes of the separate single implant-supported prostheses, which are adjacent to each other, are still insufficient, while the single-tooth implant restorations adjacent to natural teeth have shown reliable long-term clinical results [4-6]. Kwon et al. [7] reported the short-term clinical results of the separate single implant-supported crowns, which functioned well in the posterior jaws without complications other than porcelain chipping during the short period of 1 year. As the separate single implant-supported crowns, replacing consecutive multiple teeth, have been used in the patients' mouths during a long-term of 4 years, other prosthodontic or periodontal complications are anticipated to occur and are necessary to be explored.

This 4-year prospective cohort study investigated various events, including implant survival, marginal bone resorption and screw loosening, when the restorative method using unsplinted implants is employed to restore the posterior jaws.

Materials and methods

Patient selection

Subjects who had two or more consecutively missing teeth in the posterior quadrants and planned to undergo restoration by multiple single-tooth implant restorations were recruited for this prospective cohort study. From August 2008 to April 2009, eight volunteers (three men, five women) received 20 implants at Seoul National University Bundang Hospital, Seongnam, Korea. The enrolled patients were on average 46 years old at the time of implant surgery. This study included smokers and patients with diabetes mellitus or hypertension who were well-controlled under medication, while those patients who had systemic diseases affecting implant survival were excluded (Table I) [8]. This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (approval no. B-0808/029-001). All subjects signed written informed consent forms after listening to the explanation of this investigation. All patients have visited regularly for 4 years after implant installation. This prospective cohort study was designed, conducted and described according to the strengthening the reporting of observational studies in epidemiology (STROBE) statement (See Appendix) [9].

Implant surgical and prosthodontic procedures

All implants (Inplant, Warantec, Seoul, Korea) were placed on the posterior regions of patients' maxillae and mandibles with local anesthesia following the drilling sequence recommended by the manufacturer. The implants used in this study had an internal friction design for abutment connection, microthreads, a square thread design and a moderately roughened surface produced by etching and blasting [10,11]. The tops of the embedded implants were located at the bone crests with an insertion torque of over 30 Ncm. Cover screws were used after implant placement. Thread exposure area at the time of the first stage of surgery was covered with alloplast bone powder (MBCP, Biomatlante, Bretagne, France) and absorbable collagen membrane (Bio-Gide, Geistlich Pharma AG, Wolhusen, Switzerland). The cover screws were removed and healing abutments were connected with the implants at the second stage of surgery. After 3 months of implant insertion, final impressions were taken at the implant-level and the unsplinted freestanding implant-supported single crowns were delivered. The permanent restorations were made of metal-ceramics or zirconia-ceramics. Every crown had light contacts at the centric position of the mandible and no contacts at the eccentric. The final restorations were definitely cemented (Fuji-CEM, GC Corporation, Tokyo, Japan) to the implant abutments.

Table I. Demographic data and sample characteristics in this study.

Variables	No. (%)
Patient gender	
Male	3 (37.5)
Female	5 (62.5)
Patient age	
Mean age (range)	46 years (32–59 years)
Systemic disease	
Diabetes mellitus	1 (12.5)
Hypertension	1 (12.5)
Implant location	
Maxilla	9 (45)
Mandible	11 (55)
Restoration material	
Metal-ceramics	13 (65)
Zirconia-ceramics	7 (35)
Implant length	
8.5 mm	8 (40)
10.0 mm	7 (35)
11.5 mm	5 (25)
Loading duration	
48 months	20 (100)

Data collection

Patients were enrolled in a maintenance schedule and checked at 1, 3, 6, 12, 24, 36 and 48 months after prosthodontic delivery. Patients were asked to fill out a simple questionnaire to determine what, if any, problems had occurred during the intervening period.

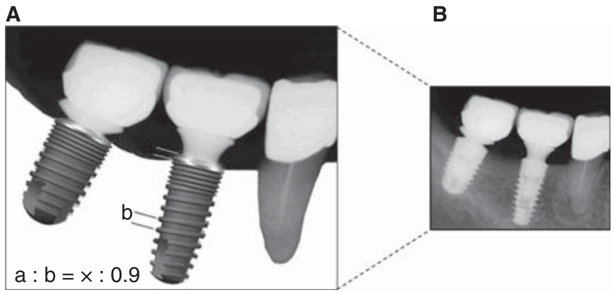

Figure 1. Possible distortion from the true dimension of the implant was accounted for. The proportional expression to calculate the actual amount of marginal bone level change is shown on the diagrammatic figure (A) for the black rectangle of the real radiographic image (B). a: Distance between the implant–abutment interface and the first visible bone to implant contact measured from radiograph. b: Pitch distance measured from radiograph. 0.9: the real pitch distance between the macrothreads (mm). x: the real amount of bone change.

Biological and technical complications such as gingival swelling or screw loosening were checked at follow-up visits. Implant mobility was manually assessed; the mobility of an implant was checked with a pincette, the tip of which was put with slight pressure on the occlusal surface of an implant-supported crown to detect mobility. Implant mobility was classified as two categories in this study; no mobility and detected mobility. Any sense of mobility was categorized as 'detected mobility'. Soft tissues were evaluated by probing for the presence or absence of the peri-implant pocket. The maximal pocket depth was recorded for every implant. Periapical radiographs were periodically taken using the long cone paralleling technique and the marginal bone loss was examined. The crestal bone level was measured from the implant–abutment interface to the bone level with the first contact to the implant (Figure 1). Calibration of the radiographic images was needed to obtain the exact crestal bone level. The pitch between the threads of the implants used in this study was 0.9 mm, which also agrees with the data the manufacturer provides. Therefore, the exact crestal bone level was obtained through proportional expression using the actual and radiographically measured values of the pitch (Figure 1). The crestal bone level at the time of prosthodontic delivery was regarded as baseline. The marginal bone loss in this study was the difference of the crestal bone levels in comparison with the baseline and each visit.

Statistics

Because of the small sample size and non-normal distribution of the outcomes of interest, non-parametric analytic methods were implemented in most cases. To compare the amount of bone loss and probing depth according to different locations (mesial or distal), material types and lengths of implants at each time point, the Wilcoxon rank-sum test and the Kruskal-Wallis test were implemented, as appropriate. For evaluation of repeated measurements at 1, 3, 6, 12, 24, 36 and 48 months, repeated measures ANOVA was used to clarify the effect of period from the implant loading. Also the changes in the interest of outcomes by the material types and length of implants over time were simultaneously investigated. Other unfavorable observations found at the end of 4 years were analyzed using Fisher's exact test, because there were multiple cells with smaller than expected frequencies. If a cell had zero observed frequencies, a small figure 0.001 was substituted instead of 'zero' frequency, for computational convenience.

Results

A total of 20 implants were inserted with nine implants (45%) on the maxilla and 11 implants (55%) on the mandible. Twenty implants comprised 13 metal-ceramic and seven zirconia-ceramic restorations and also implants of three different lengths, 8.5 mm, 10.0 mm and 11.5 mm (Table I). For 48 months after loading there was no mobility or failure of implants, showing a 100% survival rate. Mean (SD) amount of marginal bone loss around implants for 4 years was 0.26 mm (0.5 mm) and there was no significant difference in bone loss between mesial and distal bone ($p > 0.05$) (Table II). Application of the repeated measures ANOVA revealed significant changes in amount of marginal bone loss with time ($p = 0.001$) (Table III). However, the differences of bone loss between metal-ceramic and zirconia-ceramic crowns were insignificant throughout the 4-year period, although there were differences ranging from 0.15–0.27 mm in 24–48 months of periods after implant surgery. Similarly, the differences of bone loss among implants with various lengths (8.5 mm, 10 mm and 11.5 mm) were insignificant throughout 4 years, although observed differences were greater in implants of 10 mm length compared to others in periods from 24–48 months after the surgery. Mean probing depths over 4 years were similar and did not differ significantly, regardless of the materials used or length of implants (Table IV).

During 4 years after restoration, some unfavorable clinical outcomes were reported (Table V); In descending order these were; food impaction (65%), porcelain chipping (45%), sensitivity (25%) and pain (20%), followed by loose contact (15%). No screw loosening or fracture was found in this study. Zirconia-ceramic crowns showed more porcelain chipping ($p = 0.017$), pain ($p = 0.007$) and loose contact with an adjacent crown ($p = 0.031$) than metal-ceramic crowns. Porcelain chipping occurred in the zirconia-ceramic group most frequently (86%),

Table II. Amounts of marginal bone loss (mm) around implants loaded for 4 years (mean (SD)).

Periods (months)	Mean bone loss ((M + D)/2) ($n = 20$)	Mesial bone loss ($n = 20$)	Distal bone loss ($n = 20$)	p-value*
1	0.04 (0.16)	0.04 (0.14)	0.04 (0.19)	0.583
3	0.06 (0.18)	0.08 (0.15)	0.03 (0.28)	0.799
6	0.23 (0.38)	0.12 (0.41)	0.33 (0.44)	0.056
12	0.23 (0.30)	0.11 (0.39)	0.21 (0.43)	0.369
24	0.26 (0.29)	0.20 (0.32)	0.33 (0.37)	0.495
36	0.32 (0.37)	0.26 (0.44)	0.39 (0.49)	0.253
48	0.26 (0.50)	0.23 (0.45)	0.30 (0.61)	0.883

*p-value obtained by the Wilcoxon rank-sum test.

Table III. Amounts of mean (SD) marginal bone loss (mm) after implant loading.

	Material			Length of implants (mm)			
Periods (months)	Metal-ceramic	Zirconia-ceramic	p-value[a]	8.5	10.0	11.5	p-value[b]
n	13	7		8	7	5	
1	0.03 (0.19)	0.07 (0.07)	0.438	0.06 (0.94)	0.03 (0.16)	0.02 (0.26)	0.484
3	0.05 (0.22)	0.07 (0.08)	1.000	0.07 (0.09)	0.11 (0.06)	-0.06 (0.33)	0.130
6	0.20 (0.38)	0.28 (0.40)	0.877	0.30 (0.31)	0.23 (0.49)	0.11 (0.34)	0.591
12	0.11 (0.33)	0.26 (0.22)	0.211	0.24 (0.34)	0.21 (0.28)	-0.05 (0.20)	0.101
24	0.19 (0.25)	0.40 (0.34)	0.115	0.20 (0.15)	0.34 (0.39)	0.27 (0.35)	0.797
36	0.24 (0.34)	0.48 (0.42)	0.211	0.29 (0.32)	0.45 (0.44)	0.19 (0.40)	0.516
48	0.17 (0.54)	0.44 (0.38)	0.211	0.19 (0.62)	0.42 (0.42)	0.17 (0.40)	0.553
Test for all periods[#]	p-value (period) = 0.001, p-value (period × material) = 0.377			p-value (period) = 0.004, p-value (period × length) = 0.464			

[a]p-value for comparison of material types by the Wilcoxon rank-sum test.
[b]p-value for comparison of length of implants by the Kruskal-Wallis test.
[c,d]Different superscript letters indicate significant differences at $p < 0.05$.
[#]For the assessment the repeated measures ANOVA was applied and p-values were adjusted by the Greenhauser-Geisser correction method.

Table IV. Mean (SD) probing depth (mm) after implant loading.

	Material			Length of implants (mm)			
Periods (months)	Metal-ceramic	Zirconia-ceramic	p-value[a]	8.5	10.0	11.5	p-value[b]
n	13	7		8	7	5	
6	3.77 (1.17)	3.00 (1.15)	0.183	4.25 (1.03)	3.14 (1.35)	2.80 (0.45)	0.051
12	3.61 (0.96)	3.00 (1.15)	0.211	4.00^{c} (0.76)	3.28^{cd} (1.25)	2.60^{d} (0.54)	0.044
24	3.61 (0.87)	3.85 (1.57)	1.000	4.00 (0.53)	3.14 (1.35)	4.00 (1.41)	0.098
36	3.84 (1.28)	3.86 (1.57)	0.877	4.00^{cd} (0.53)	3.00^{c} (1.41)	4.80^{d} (1.64)	0.049
48	3.84 (1.28)	4.00 (1.41)	1.000	4.00 (0.53)	3.14 (1.35)	4.80 (1.64)	0.064
Test for all periods[#]	p-value (period) = 0.168, p-value (period × material) = 0.262			p-value (period) = 0.055, p-value (period × length) = 0.009			

[a]p-value for comparison of material types by the Wilcoxon rank-sum test.
[b]p-value for comparison of length of implants by the Kruskal-Wallis test.
[#]For the assessment the repeated measures ANOVA was applied and p-values were adjusted by the Greenhauser-Geisser correction method.

while food impaction was the most frequent event in the metal-ceramic group (69%). Most of the porcelain chipping events had an affected surface area less than 2 mm^2.

Discussion

This prospective study showed that unsplinted implant-supported single restorations were functional

Table V. Unfavorable clinical outcomes found after 4 years from implant loading.

Complications	Metal-ceramic	Zirconia-ceramic	Total	*p*-value*
Food impaction	9	4	13 (65%)	0.651
Porcelain chipping	3	6	9 (45%)	0.017
Sensitivity	2	3	5 (25%)	0.290
Pain	0†	4	4 (20%)	0.007
Loose contact with proximal tooth or implant	0	3	3 (15%)	0.031
Severe hard contact with proximal tooth or implant	0	2	2 (10%)	0.111
Tongue bite	0	2	2 (10%)	0.111
Clenching	0	2	2 (10%)	0.111
Gingival bleeding	0	2	2 (10%)	0.111
Gingival swelling	0	2	2 (10%)	0.111
Malodor	0	2	2 (10%)	0.111
Thread or metal exposure	2	0	2 (10%)	0.521
Gingival redness	1	0	1 (5%)	1.000
Screw hole fracture	0	1	1 (5%)	0.350
Mobility	0	0	0 (0%)	N/A
Total	13	7	20 (100%)	

*By the Fisher's exact test because of the small expected frequencies.
†A value 0.001 was imputed instead of 'zero' frequencies for computational convenience.
N/A, Not available.

in terms of marginal bone resorption for a 4-year period. Previously, we also showed favorable results in a prospective cohort study for up to 1 year [7]. Although some minor complications which did not jeopardize implant success were reported during follow-up periods, single restored implants functioned well, with less than 0.5 mm of marginal bone loss. In addition, stable periodontal status was also shown.

These results followed on from and generally agreed with findings from those of prior investigations [3,12]. The internal friction connection between an implant and an abutment, micro threads at the crestal area of an implant, and moderately roughened surface were considered to contribute to favorable results of marginal bone loss [13-15]. However, the exact resorption mechanism of the bone according to the implant–abutment connection type appears to be controversial [16,17]. Further sophisticated comparison studies are still required to clarify the bone loss mechanism, although a recent meta-analytic study [18] reported that the 5-year survival rate of implant-supported single crowns was over 95% and that bone loss of >2 mm was seen in ~5%. Additionally, implant lengths were shown to have no significant effect on marginal bone loss or implant survival in the treatment modality used in this study, which is supported by two previous studies [19,20].

Most importantly, this study indicated that complication events require greater attention than only implant survival or marginal bone loss, when the unsplinted implant-supported single crowns are used for restoration of missing adjacent multiple teeth. A previous study [1] reported difficulty in contact adjustment between the implant-supported single crowns, which this investigation confirmed by showing a high prevalence of food impaction. The introduction of zirconia resulted in more natural-looking restoration, but the bond problem between the zirconia core and the veneering porcelain needs solving [21,22]. The present study indicated more frequent occurrence of the porcelain chipping events in the zirconia-ceramic group than in the metal-ceramic group, although the sample size was limited. Other previous studies [23-25] also reported that there were more clinical complications with zirconia ceramic restorations than with metal ceramic restorations.

In practice, it is difficult to evaluate the exact bone loss radiographically because distortion and elongation of the image occurs due to the differences in radiation exposure and x-ray angulation. This study tried to find the true amount of marginal bone resorption by using proportional expressions with the known value of the implant thread pitch and by applying negative color to the radiographic images, which techniques were also used by other previous investigations [7,26]. However, the inability to observe the images three-dimensionally was still a limitation of this study. The small sample size made the interpretation of data difficult. For example, a clear analysis of why there was more pain in zirconia-ceramic restorations than in metal-ceramic restorations could not be clarified in detail, despite the significant difference between the groups.

This 4-year prospective cohort study concluded that consecutive unsplinted implant-supported single restorations may be functionally effective to replace lost multiple adjacent posterior teeth, although the sample size was limited. However, dental clinicians should recognize the difficulty in contact adjustment between restorations and the high prevalence of food impaction in this prosthodontic treatment modality.

Acknowledgment

The authors are indebted to Professor Emeritus J. Patrick Barron (Tokyo Medical University, Tokyo, Japan and Adjunct Professor, Seoul National University Bundang Hospital, Seongnam, Korea) for his pro bono editing of this manuscript.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Supplementary materials available online

Appendix