Impact of Platform Switching on Peri-Implant Bone Remodeling around Short Implants in the Posterior Region, 1-Year Results from a Split-Mouth Clinical Trial

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ABSTRACT

Aim: To assess the effect of platform switching on peri-implant bone remodeling around short implants (8.5 mm) placed in the resorbed posterior mandibular and maxillary region of partially edentulous patients.

Materials and Methods: Seventeen patients with one or more missing teeth at both sides in the posterior region were, according to a split-mouth design, randomly assigned to be treated with a platform-matched (control) implant on the one side and a platform-switched implant (test) on the other side. A total of 62 short implants (8.5 mm) with a dual-acid etched surface with nanometer-sized calcium phosphate particles was placed. Follow-up visits were conducted one month and one year after placing the implant crown. Outcome measures were interproximal bone level changes, implant survival and clinical parameters.

Results: One year after loading, peri-implant bone remodeling around test implants (0.53 ± 0.54 mm) was significant less than around control implants (0.85 ± 0.65 mm; $p = .003$). With regard to implant survival and clinical parameters no significant differences were observed between test and control implants.

Conclusions: This study suggested that peri-implant bone remodeling is affected by platform switching. One year after loading, interproximal bone levels were better maintained at implants restored according to the platform switching concept.

KEY WORDS: bone remodeling, CaP, dental implants, nano roughness, platform switching, short implants

INTRODUCTION

From the moment the healing abutment is placed and the implant is exposed to the oral environment, biologic width formation starts. A mucosal attachment of a certain minimum vertical dimension (3–4 mm) is formed and, as a consequence, crestal bone resorption may take place.[1,2] Whether or not crestal bone resorption will occur depends, among others, on the presence of a microgap between implant and abutment and on the location of this microgap in relation to level of the crestal bone. One-piece implants (no microgap) and implants placed above the alveolar crest have been show to prevent crestal bone resorption.[2–5] The implant-abutment connection is also thought to be an important factor regarding peri-implant bone remodeling as the highest number of inflammatory cells has been observed at the implant-abutment interface.[4]

The implant-abutment configuration itself is also thought to affect peri-implant remodeling of bone. In so-called platform-switched implants, the diameter of the abutment is less than the diameter of the implant,

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resulting in a horizontal offset at the top of the implant that separates the crestal bone and the connective tissue from the interface. Early results of these platform-switched implants showed no changes in peri-implant bone levels, contrary to standard platform-matched implants.[6] Next, several hypotheses were posed to explain the rationale behind the concept of platform switching for crestal bone preservation. The biomechanical rationale proposed that by platform switching the stress-concentration zone (from the forces of occlusal loading) is directed from the crestal bone–implant interface to the axis of the implant and so reduces the stress level in the cervical bone area.[7] Cochran et al.[3] showed that placing the implant-abutment connection below the crestal bone level may cause bone resorption to reestablish the biologic width. Following this theory, platform switching medializes the microgap and the dimension of the biologic width. A horizontal mismatch of 0.3 mm was found to decrease the vertical dimension of the junctional epithelium.[8,9] Another hypothesis concerned the role of inflammatory cell infiltrate at the implant-abutment connection. The presence of peri-implant microbiota was suggested to influence crestal bone resorption by maintaining the inflammatory cell infiltrate within the implant-abutment connection.[4,10,11] However, no association was found between crestal bone resorption and peri-implant microbiota at platform-matched and platform-switched implants.[12]

Preclinical data of Cochran et al.[3] showed minimal histologic bone remodeling of platform-switched implant. Their data were in contrast to the preclinical data described by Becker et al.,[8,13] who concluded that platform switching may not be of crucial importance for maintenance of the crestal bone level. From the systematic review of the literature, Atieh et al.[14] concluded that marginal bone loss around platform-switched implants was significantly less compared to platform-matched implants (0.021–0.99 mm for platform-switched and 0.101–1.67 mm for platform-matched implants).[15–25] However, no long-term data are present. The large variation in results was thought to be due to the use of different implant diameters, mismatches and implant systems. Moreover, 3 of the 10 included studies reported no differences in bone level changes between the platform concepts tested.[18,19,21]

Short implants (<10 mm in length) are increasingly used as there is fair evidence that short implants can be placed successfully in the partially edentulous patient, but with a tendency toward an increasing survival rate per implant length.[25] Therefore, it is important to preserve peri-implant bone, especially in short implants. However, short implants might be expected to develop a greater maximum compressive stress in their coronal region in comparison to longer implants, which could lead to bone microfracture and crestal bone resorption.[26]

To our knowledge no study with a split-mouth design, has been reported about the effectiveness of platform switching. The rationale for a split-mouth design was to remove all components related to differences between subjects from the treatment comparisons. By making within-patient comparisons, rather than between-patient comparisons, the error variance (noise) of the experiment can be reduced, thereby obtaining a more powerful statistical test. As implant surface roughness affects bone response an implant with a relatively new implant surface was chosen; a dual acid-etched surface with a nanometer-sized deposition of calcium phosphate (CaP).[27–30] Histological and histomorphometric studies showed acceleration of early peri-implant bone healing, but no long-term data are present.[31–33] Therefore, the aim of this study was to assess the effect of platform switching on peri-implant bone remodeling around short implants (8.5 mm) placed in the resorbed posterior mandibular and maxillary region of partially edentulous patients.

MATERIALS AND METHODS

Patients

Partially edentulous patients referred for implant therapy in the posterior region, in the years 2007 until 2010, to the Department of Oral and Maxillofacial Surgery of the University Medical Center Groningen (The Netherlands), were considered for inclusion if they fulfilled the following criteria:

- at least 18 years of age;
- capable of understanding and giving informed consent;
- one or more missing teeth being a premolar and/or molar in the maxilla right and left side or one or more missing teeth being a premolar and/or molar in the mandible right and left side; and
- at the place of the future implant a maximum of 10 mm bone in vertical dimension and minimum of 8 mm in horizontal dimension available.

Exclusion criteria were:

- medical and/or general contraindications for the surgical procedures (ASA score ≥III);[34]
- presence of active clinical periodontal disease in the dentition as expressed by probing pocket depths ≥5 mm and bleeding on probing;
- presence of peri-apical lesions or any other abnormalities or infections at the implant site as determined on a radiograph;
- smoking; and
- a history of radiotherapy to the head and neck region.

Study Design

This study was approved by the Medical Ethical Committee of the University Medical Center Groningen. Before enrolment, written and verbal information was given to the patients and written informed consent was obtained.

Two different implant-abutment connections were studied on implants with a length of 8.5 mm. The platform-switched implants (Certain Prevail, Biomet 3i, Palm Beach Gardens, FL, USA) used in the test group had a horizontal mismatch of 0.35 mm and 0.40 mm, respectively, for the implants with a diameter of 4 and 5 mm. In a vertical dimension, the implant-abutment connection lied 0.09 mm and 0.11 mm, for implants with a diameter of 4 and 5 mm, respectively, above the implant shoulder (Figures 1A and 2A). The control implants (XP Certain, Biomet 3i) had the same dimensions as the platform-switched implants except for the implant-abutment connection, which was platform-matched (Figures 1B and 2B). Both implant types had an extended platform and a dual-acid etched (using hydrochloric and sulfuric acids) surface with a discrete crystalline deposition of nanometer-sized CaP particles (NanoTite, Biomet 3i). Implants with a platform-matched (control) or a platform-switched implant-abutment connection (test) were randomly assigned to the left or right side of the jaw. An investigator with no clinical involvement in the trial informed the surgeon, who inserted the implants, about the allocation result on the day of surgery, just before implant surgery was started. The prosthodontist was informed about the allocation result before the impression of the healing abutment was made. The surgeon and prosthodontist could not be blinded for the allocation result as they could see by the inner color of the implant whether the implant placed was a test or control implant.

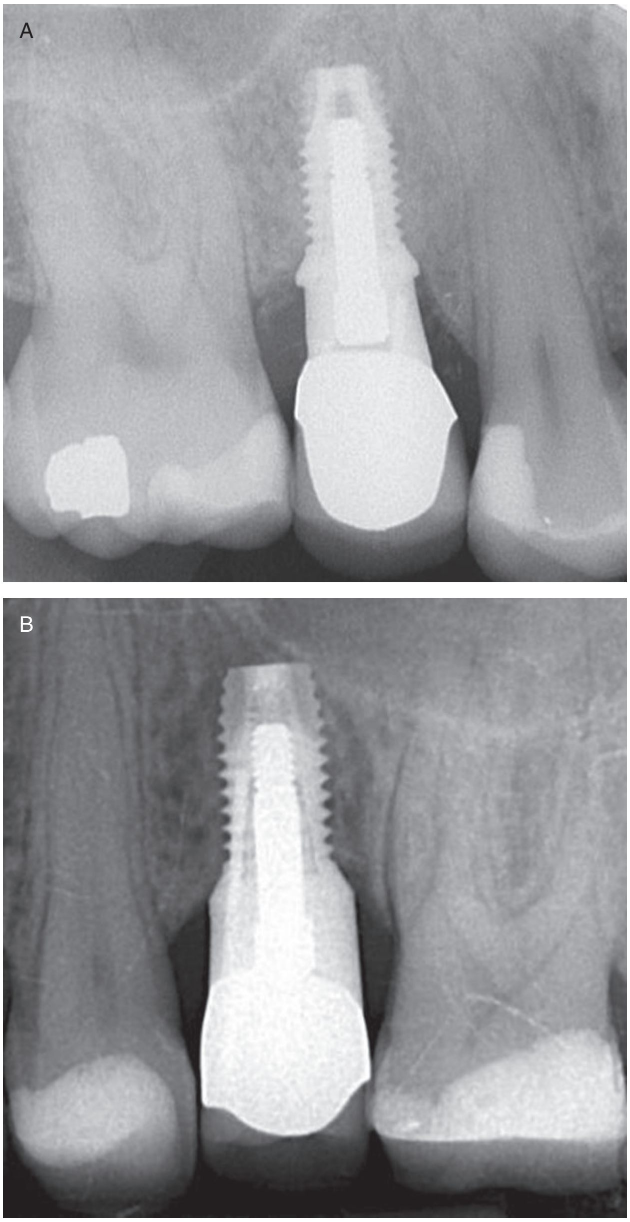

Figure 1 (A) Dental radiograph of a platform-switched implant. (B) Dental radiograph of a platform-matched implant.

Interventions

All patients were treated at the department of Oral and Maxillofacial Surgery of the University Medical Center Groningen. All implants (left and right side) were placed in the same surgery, in healed sites, that is, at least 3–4 months after tooth removal allowing the extraction site to have healed. Implants were placed and restored according to the protocol described in detail

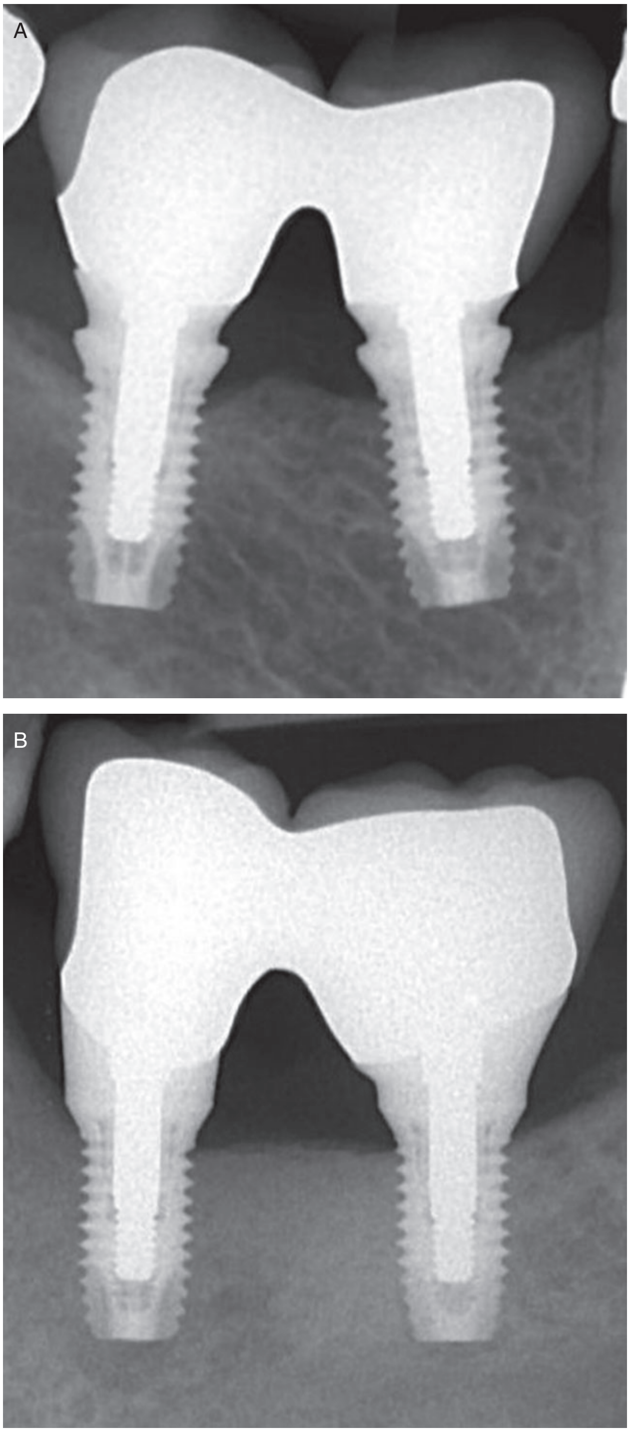

Figure 2 (A) Dental radiograph of two adjacent platform-switched implants. (B) Dental radiograph of two adjacent platform-matched implants.

previously.[35] Briefly, the incision was made on the top of the alveolar crest and a surgical template was used. The implant shoulder was placed at bone level, both mesial and distal even with the alveolar crest, and if necessary, the bone was flattened. The distance between the implant and the neighboring teeth was at least 1.5 mm, and the distance between two implants was at least 3 mm. On this implant, a coded healing abutment (Encode®, Biomet 3i) with a height of 4 mm was placed to develop an emergence profile. Next, if any, implant dehiscences or fenestrations at the buccal side of the implant were covered with autogenous bone chips collected during implant bed preparation and anorganic bovine boss (Bio-oss®, Geistlich Pharma AG, Wolhusen, Switzerland) overlaid with a collagen membrane (Bio-Gide®, Geistlich Pharma AG). Finally, the wound was closed with sutures (Vicryl® 3–0, Johnson & Johnson, Brunswick, NJ, USA). Two weeks following implant surgery, the sutures were removed. Three months after implant placement, seating of the healing abutment was evaluated and impressions were made. The healing abutment was scanned from the cast and an individualized abutment was milled according to the procedure described by Telleman et al.[35] The abutment was placed with 20 Ncm and the metal ceramic crown was cemented (GC Fuji 1, GC Europe NV, Leuven, Belgium).

All surgical procedures were performed by a single experienced oral and maxillofacial surgeon. Six experienced prosthodontics performed the prosthetic procedure.

Outcome Measures

The primary outcome measure was the mean interproximal bone level change (mesial and distal sides combined) from the time of implant placement (baseline) to 1 year after placing the crown on the implant; which is 16 months after placing the implant (T_{16m}) as measured on standardized digital radiographs. Secondary outcome measures were implant survival and changes in marginal soft tissue-level of the implant and the neighboring teeth. One and the same examiner performed all measurements. To assess the reliability of the radiographic examination, this examiner was assisted by a second examiner. The operationalization of the variables is described as follows.

Radiographic Assessments

After implant placement (T_{0m}), 1 month (T_{5m}) and 1 year after placing the implant crown (T_{16m}), standardized digital intra-oral radiographs were taken according to a long-cone paralleling technique as described by

Meijndert et al.[36] Interproximal bone level changes were measured using specifically designed computer software (Dicomworks version 1.0, Department of Biomedical Engineering, University Medical Center Groningen, The Netherlands). The calibration was carried out in the vertical plane for each radiograph, by using the known distance of several threads. This calibration ensured a correct measurement.[37] The outermost margin of the implant shoulder was used as the reference point to assess the interproximal vertical bone level change. To assess the reliability of the radiographic examination 30 radiographs of 10 patients were assessed by two examiners. The inter-observer agreement was tested on 60 measurements (3 radiographs $\times$ 10 patients $\times$ 2 [mesial, distal] bone level assessments) of the first examiner and 60 measurements of the second examiner.

Clinical Assessments

Pre-operatively (T_{pre}), 1 month (T_{5m}) and 1 year (T_{16m}) after the placement of the implant crowns, the soft-tissue around the implants and their neighboring teeth were clinically examined using the following clinical parameters:

- Assessment of plaque accumulation with the modified Plaque Index;[38]
- Assessment of bleeding tendency with the modified Sulcus Bleeding Index;[38]
- Assessment of peri-implant inflammation with the Gingival Index;[39]
- Presence of dental calculus; and
- Sulcus probing pocket depth: measured to the nearest millimeter using a manual periodontal probe (Williams Color-Coded Probe; Hu-Friedy, Chicago, IL, USA).

Statistical Analysis

To assess the inter-observer agreement for the continuous variables of the peri-implant bone level changes (scored on peri-apical radiographs) two way random models were used to calculate the intraclass correlation coefficient.

To see whether the data were normally distributed the frequency distribution was plotted in a histogram (Figure 3). To test whether the result from the frequency analyses differed significantly from a normal distribution Kolmogorov-Smirnov and Shapiro-Wilk tests were done. For between-groups comparisons of normally distributed variables, *t*-tests were used. Variables that were not normally distributed were statistically explored using Mann-Whitney tests.

In all analyses, a significance level of $p < .05$ was chosen. Data were analyzed using *SPSS*® 16.0 (SPSS Inc., Chicago, IL, USA).

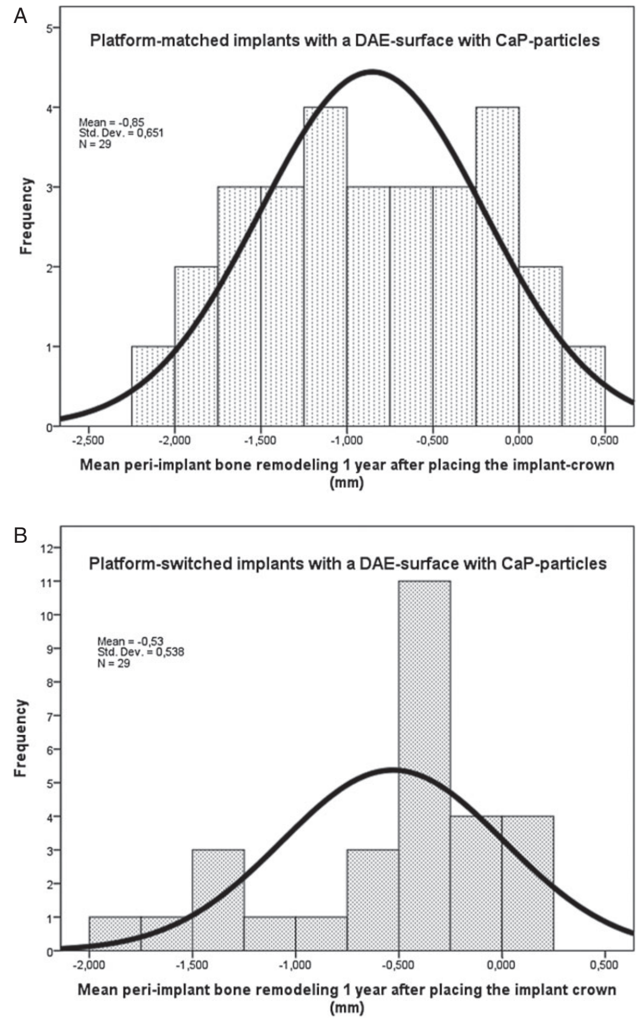

Figure 3 Frequency distributions of the mean peri-implant bone remodeling of the 29 platform-matched (A) and 29 platform-switched (B) implants supplied. The platform-matched implants show a normal distribution ($D(29) = 0.121$, $p = .200$, $W(29) = 0.968$, $p = .498$). The frequency distribution of the platform-switched implants differ significantly from a normal distribution and show a negative kurtosis ($D(29) = 0.201$, $p = .004$, $W(29) = 0.893$, $p = .007$).

RESULTS

Patients

Between May 2007 and December 2009, a total of 17 patients fulfilled the inclusion criteria. Baseline patients

TABLE 1 Baseline Characteristics of the Patients

Variable	Platform-Matched Implant-Abutment Connection (*n* = 17; control)	Platform-Switched Implant-Abutment Connection (*n* = 17; test)
Mean age ± SD and range (years)	53.7 ± 11.7 (21–67)	53.7 ± 11.7 (21–67)
Female/male ratio	17/0	17/0
Implant position:		
Maxillary $P_1/P_2/M_1/M_2$	2/3/4/3	3/2/5/2
Mandibular $P_1/P_2/M_1/M_2$	1/9/8/1	1/8/8/2
Number of implants to be placed in a patient:		
1	4	4
≥2 adjacent implants	13	13
Implant diameter:		
4.1 mm	27	26
5.0 mm	4	5

and treatment characteristics are listed in Table 1. There was no drop-out; all patients attended the follow-up visits.

Peri-Implant Bone Remodeling

The intraclass correlation coefficient for average measures was 0.867 for the radiographic inter-observer agreement (Cronbach's alpha = 0.867), which can be interpreted as almost perfect agreement.[40]

Overall, mean peri-implant bone remodeling was significantly less around platform-switched implants than around implants with platform-matched implant-abutment connections, both 1 month and 1 year after placing the crown (Table 2). However, when comparing bone remodeling in cases provided with one implant no difference between the two platform designs was observed, while when two or more adjacent platform-switched implants were placed bone remodeling was significantly less comparing to platform-matched implants, 1 month and 1 year after placing the crown (Table 2).

Implant Survival

Two of 31 platform-matched implants and 2 of the 31 platform-switched implants were lost, both resulting in a survival rate of 93.6%. All implants were lost before loading, three in the maxilla and one in the mandible.

Clinical Outcome

The mean probing pocket depth around the implants did not significantly increase between T_{5m} and T_{16m} (Table 2). Also, no between-group differences in clinical parameters plaque accumulation, bleeding tendency, gingiva index (Table 3) were observed.

DISCUSSION

After 1 year in function, the results of our split-mouth study showed significantly less peri-implant bone remodeling around short platform-switched implants compared to platform-matched implants placed in the resorbed posterior region of partially dentate patients. This effect was only observed when two or more implants were placed, and did not count for single tooth replacement. A reason could be the low numbers of single tooth replacements in this study. Three of the 10 studies in the systemic review of Atieh et al.[14] to platform switching reported also no differences in bone level changes between the two platform designs.[18,19,21] Although Atieh et al.[14] concluded that platform-switched implants show less marginal bone loss. The large variation in peri-implant bone remodeling reported in the review was thought to be due to the use of different implant diameters, mismatches, and implant systems. Clearly, the concept of platform switching is not sufficiently verified yet and thus not solid evidence-based, as long-term data about the effect of platform switching and about the different platform switching designs are lacking. Furthermore, not much is written about the difference in bone remodeling around single or multiple adjacent platform switching implants. Atieh et al.[14] stated that these implants may preserve inter-implant bone height, but they could not confirm the validity of that concept.

TABLE 2 Changes in Peri-Implant Bone Level and Pocket Probing Depths at Implant and Tooth Sides from Baseline to 16 Months after Placement of the Implant

	T_{0m}–T_{5m}		T_{5m}–T_{16m}		T_{0m}–T_{16m}	
All Implants	Platform-Matched (n = 31)	Platform-Switched (n = 31)	Platform-Matched (n = 31)	Platform-Switched (n = 31)	Platform-Matched (n = 29)	Platform-Switched (n = 29)
Implant bone-level changes (mm)	−0.82 (±0.59)*	−0.44(±0.57)*	−0.01(±0.34)	−0.09(±0.36)	−0.85(±0.65)**	−0.53(±0.54)**
	T_{0m}–T_{5m}		T_{5m}–T_{16m}		T_{0m}–T_{16m}	
1 Implant	Platform-Matched (n = 4)	Platform-Switched (n = 4)	Platform-Matched (n = 4)	Platform-Switched (n = 4)	Platform-Matched (n = 4)	Platform-Switched (n = 4)
Implant bone-level changes (mm)	−0.41(±0.31)	−0.15(±0.36)	0.08(±0.15)	−0.20(±0.38)	−0.33(±0.36)	−0.35(±0.19)
Pocket probing depth changes (mm)						
Implant	Not available	Not available	−0.06(±0.85)	−0.44(±1.00)	−0.06(±0.85)	−0.44(±1.00)
Tooth mesially of the implant	0.13(±0.52)	0.31(±0.31)	−0.13(±0.25)	−0.06(±0.31)	0.00(±0.35)	0.25(±0.46)
Tooth distally of the implant	−0.42(±0.29)	0.50(±0.35)	0.42(±0.52)	0.25(±0.65)	0.00(±0.66)	0.75(±0.00)
	T_{0m}–T_{5m}		T_{5m}–T_{16m}		T_{0m}–T_{16m}	
2 or More Implants	Platform-Matched (n = 27)	Platform-Switched (n = 27)	Platform-Matched (n = 27)	Platform-Switched (n = 27)	Platform-Matched (n = 25)	Platform-Switched (n = 25)
Implant bone-level changes (mm)	−0.89(±0.60)***	−0.49(±0.59)***	−0.02(±0.36)	−0.07(±0.36)	−0.94(±0.65)****	−0.56(±0.57)****
Pocket probing depth changes (mm)						
Implant	Not available	Not available	−0.19(±0.72)	−0.36(±0.61)	−0.19(±0.72)	−0.36(±0.61)
Tooth mesially of the implant	−0.02(±0.54)	0.00(±0.51)	−0.06(±0.41)	−0.06(±0.54)	−0.08(±0.37)	−0.06(±0.45)
Tooth distally of the implant	Not available	Not available	Not available	Not available	Not available	Not available

Negative results in implant bone level changes indicate peri-implant bone remodeling and positive results in pocket probing depth changes indicate deepened peri-implant pockets.
For between groups comparisons: *p = .003, **p = .066, ***p = .005, ****p = .040.

TABLE 3 Clinical Parameters of Implants and Adjacent Teeth

	% at T_{0m}		% at T_{5m}		% at T_{16m}	
Clinical Parameters	Platform-Matched	Platform-Switched	Platform-Matched	Platform-Switched	Platform-Matched	Platform-Switched
Implant Plaque Index[38]						
Score 0, no detection of plaque	—	—	89.7	93.1	65.5	82.8
Score 1, plaque on probe	—	—	10.3	6.9	17.2	6.9
Score 2, plaque seen by naked eye	—	—	0	0	17.2	10.3
Score 3, abundance of soft matter	—	—	0	0	0	0
Implant Bleeding Index[38]						
Score 0, no bleeding	—	—	69.0	79.3	65.5	75.9
Score 1, isolated bleeding spots	—	—	31.0	20.7	27.6	20.7
Score 2, confluent line of blood	—	—	0	0	6.9	3.4
Score 3, heavy or profuse bleeding	—	—	0	0	0	0
Implant Gingival Index[39]						
Score 0, normal mucosa	—	—	93.1	100	82.8	93.1
Score 1, mild inflammation	—	—	6.9	0	17.2	6.9
Score 2, moderate inflammation	—	—	0	0	0	0
Score 3, severe inflammation	—	—	0	0	0	0
Implant dental calculus						
Score 0, no dental calculus	—	—	100	100	100	100
Score 1, dental calculus present	—	—	0	0	0	0
Adjacent teeth Plaque Index[38]						
Score 0, no detection of plaque	82.6	72.7	90.5	95.2	100	90.5
Score 1, plaque on probe	17.4	27.3	4.8	4.8	0	4.8
Score 2, plaque seen by naked eye	0	0	4.8	0	0	4.8
Score 3, abundance of soft matter	0	0	0	0	0	0
Adjacent teeth Bleeding Index[38]						
Score 0, no bleeding	91.3	86.4	81.0	95.2	95.5	90.5
Score 1, isolated bleeding spots	8.7	13.6	19.0	4.8	4.5	9.5
Score 2, confluent line of blood	0	0	0	0	0	0
Score 3, heavy or profuse bleeding	0	0	0	0	0	0
Adjacent teeth Gingival Index[39]						
Score 0, normal mucosa	100	100	100	100	100	100
Score 1, mild inflammation	0	0	0	0	0	0
Score 2, moderate inflammation	0	0	0	0	0	0
Score 3, severe inflammation	0	0	0	0	0	0
Adjacent teeth dental calculus						
Score 0, no dental calculus	100	100	95.2	95.2	100	100
Score 1, dental calculus present	0	0	4.8	4.8	0	0

No significant differences were found between platform-matched and platform-switched implants up to 16 months after placement of the implant.

This trial showed similar implant survival rates for both platform designs, comparable to the survival rates reported by Atieh et al.[14] However, the survival rates of the current study were lower than the rates reported for 8.5 mm implants (98.8%; 95% CI: 98.2–99.6%) in the systematic review to short implants.[25] A reason for the lower survival rates in the current study could be the number of implants placed in the maxilla as one of the conclusions of the review to short implants was that the failure rate of studies performed in the maxilla was 0.010 implants/year compared to 0.003 implants/year in the mandible.

Also, no between-group significant differences in the clinical parameters plaque accumulation, bleeding tendency and gingiva index was observed. However, there was a tendency for platform-matched implants to have slightly more plaque and signs of mild inflammation. Considering the small difference, coming up with possible causes for this clinical observation would be pure speculation. The overall results of the clinical parameters are in accordance with the results of the histological study of Canullo et al.,[41] who concluded that switching and traditional platform implants had similar histological and soft tissue features, despite different bone level changes. Furthermore, Dellavia et al.[42] concluded that platform switching apparently did not affect the inflammatory cellular and molecular pattern around the implant-abutment connection.

The platform-switched implants applied in our trial had an implant-abutment diameter difference in horizontal dimension of 0.35 or 0.40 mm (depending on the diameter of the implant). Atieh et al.[14] reported that subgroup analyses showed that an implant-abutment difference of ≥0.4 mm was associated with a more favorable response. A bigger mismatch is often caused, as in the current study, by the use of a wider diameter. It has been speculated that the findings of reduced bone remodeling accompanying a larger implant-abutment difference may be due to an increased implant diameter rather than to the platform.[19] However, the study of Canullo et al.[43] on the impact of implant diameter of platform-switched implants clearly concluded no relation between implant diameter and extent of bone remodeling.

In the platform-switched implants we used, the implant-abutment connection is 0.09 and 0.11 mm (depending on the diameter of the implant) above the outermost margin of the collar of the implant, so when placed a bone level, as in the current study, the implant-abutment connection is slightly higher. From the study of Cochran et al.[3] we now know that the least bone remodeling was shown with the platform-switch situated 1 mm above the alveolar crest.[3] Conversely, Veis et al.[44] reported the least bone remodeling when implants were placed subcrestal. These contrasting results points to the need of additional comparative studies to the different designs (in horizontal and vertical dimension) and level of placement of platform-switched implant-abutment connection.

Generally spoken about split-mouth designs, comparisons made on a within-patient basis may have potential disadvantages.[45] One treatment concept may effect another treatment (carry-across effects). To what extent this is the case in the current study, is difficult to say. But with only a small difference between the two implant-abutment connections, placed in one and the same surgical treatment, is probably of minor influence. Another disadvantage is the recruitments of patients, which is hampered by the need for symmetrical edentulism in the posterior region. This restriction might bias the selection of patients toward those with a higher risk for cavities and possibly poorer brushing and dietary behavior.

In conclusion, this study suggested that peri-implant bone remodeling is affected by platform switching. One year after loading, interproximal bone levels were better maintained at implants restored according to the platform-switching concept.

CONFLICT OF INTEREST AND SOURCE OF FUNDING

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