Influence of Vertical Soft Tissue Thickness on Crestal Bone Changes Around Implants with Platform Switching: A Comparative Clinical Study

Tomas Linkevicius, DDS, Dip Pros, PhD;* Algirdas Puisys, DDS;† Marius Steigmann, DDS;‡ Egle Vindasiute, DDS;§ Laura Linkeviciene, DDS, PhD¶

ABSTRACT

Background: Numerous studies have shown the superiority of platform-switched implants in preserving crestal bone as compared with platform-matched implants. However, the influence of initial soft tissue thickness on development of crestal bone loss has not been addressed in previous studies; thus, further research is needed.

Purpose: To evaluate crestal bone levels around platform-switched implants placed in thin and thick mucosal tissue.

Materials and Methods: Eighty patients (38 male and 42 female, mean age 44 ± 3.34 years) received 80 bone-level implants of 4.1 mm in diameter with platform switching (Institut Straumann AG, Basel, Switzerland). Tissue thickness was measured, and cases were distributed to Group 1, with thin soft tissue (2 mm or less, $n = 40$), and Group 2, with thick tissue (more than 2 mm, $n = 40$). Implants were placed with a one-stage approach and restored with screw-retained restorations. Radiographic examination was performed after implant placement, 2 months after healing, after restoration, and at 1-year follow-up post-reconstruction. Crestal bone loss was calculated. The Mann-Whitney *U*-test was applied, and significance was set to $p \leq .05$.

Results: Implants in Group 1 (thin tissue) showed 0.79 mm of bone loss after 2 months. After 1-year follow-up, bone loss was 1.17 mm. Implants in Group 2 (thick tissue) showed bone loss of 0.17 mm after 2 months of implant placement and 0.21 mm after 1-year follow-up. The differences between groups were significant ($p < .001$) at both time points.

Conclusions: It can be concluded that platform switching does not prevent crestal bone loss if, at the time of implant placement, mucosal tissue is thin. In thick soft tissue, use of platform-switched implants maintained crestal bone level with minimal remodeling.

KEY WORDS: clinical study, crestal bone loss, implant design

INTRODUCTION

Platform switching has become a standard feature in the design of conventional implants. Its introduction has expanded the possibilities of crestal bone preservation, as numerous studies have reported reduced bone resorption for platform-switched implants compared with platform-matched implants. Cappiello and colleagues[1] found a significant bone-protective effect of platform switching, equal to 0.72 mm, in a controlled clinical trial with 131 implants in 45 patients. Prosper and colleagues[2] and Canullo and colleagues[3] have also shown the superiority of platform-switched implants over regular implants with regard to development of crestal bone stability. Recent systematic reviews unanimously confirm that implants with platform switching

*Associate professor, Institute of Odontology, Faculty of Medicine, Vilnius University, research director, Vilnius Research Group, and prosthodontist, Vilnius Implantology Center, Vilnius, Lithuania; †research associate, Vilnius Research Group, and periodontologist, Vilnius Implantology Center, Vilnius, Lithuania; ‡visiting professor, Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, MI, USA; §research associate, Vilnius Research Group, and general practice dentist, Vilnius Implantology Center, Vilnius, Lithuania; ¶lecturer, Institute of Odontology, Faculty of Medicine, Vilnius University, Vilnius, Lithuania

Corresponding Author: Dr. Tomas Linkevicius, Institute of Odontology, Faculty of Medicine, Vilnius University, Zalgirio str. 115/117, LT-08217, Vilnius, Lithuania; e-mail: linktomo@gmail.com

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preserve crestal bone better than implants with matching abutments.[4–6] From a technical point of view, platform switching results in a horizontal displacement of the implant-abutment microgap away from the bone crest. The microgap is one of the major factors responsible for bone remodeling in the apical direction.[7–11] However, other factors, such as implant neck polishing[12,13] and mucosal tissue thickness,[14] have been shown to take part in the etiology of crestal bone loss as well. Linkevicius and colleagues[15] previously published a pilot study showing that platform switching might not be effective in preventing bone loss if at the time of implant placement mucosal tissues were 2 mm or less in thickness. However, the sample size, with only 12 implants evaluated in 4 patients, precluded definitive conclusions. Nevertheless, there are data from randomized controlled clinical trials that do not confirm the hypothesis that platform switching is enough to reduce bone loss.[16,17] Some of the studies on platform switching show a wide diversity of crestal bone loss figures, ranging from 0.3 mm to 1.3 mm.[18] Recently it has been suggested that bone resorption may be mainly related to biological factors rather than to biomechanical factors like implant diameter.[19] Furthermore, the study by Vandeweghe and DeBruyn showed that platform switching is only effective when mucosal thickness allows the establishment of a biological width.[20] It is very interesting to note that most of the studies on platform switching did not evaluate vertical mucosal tissue thickness at implant placement. Hence, the effect of vertical soft tissue thickness on crestal bone level around implants with platform switching is still not clear. The purpose of this study was therefore to evaluate how crestal bone level is maintained around platform-switched implants in relation to soft tissue thickness. The null hypothesis was that there was no influence of soft tissue thickness on bone levels around implants with a horizontally altered implant-abutment connection.

MATERIALS AND METHODS

Patients

Patients at the Vilnius Implantology Center Clinic (Vilnius, Lithuania) were enrolled in this comparative clinical trial. Patients were included if they were at least 18 years old and were in general good health with no medical contraindication for implant surgery. Additional inclusion criteria were missing teeth in the lower jaw molar area, a minimum 6 mm bone width and 8 mm bone height, healthy soft tissue (bleeding on probing [BOP] < 20%, Periodontal Index [PI] < 25%, Community Periodontal Index of Treatment Needs < 2),[20] a minimum of 4 mm keratinized gingiva buccolingually, no bone augmentation procedures before or during implant placement, and finally primary implant stability of 35 Ncm to allow single-stage surgery with simultaneous connection of healing abutment. Patients were excluded if they had a history of periodontitis, were smokers, reported uncontrolled diabetes and/or alcoholism, or were taking medication that might affect tissue healing. Each patient received verbal and written instructions and signed the informed consent form, giving permission to use data obtained for research purposes. The study protocol was approved by the Vilnius regional ethical committee for biomedical trials (No. 158200-07-512-149).

Tissue Measurement, Implant Placement, and Prosthetic Restoration

All surgical interventions were performed by the same surgeon (A.P.). Before the start of implant placement, all patients received a 1 g dose of amoxicillin (Ospamox, Biochemie, Kiel, Germany). A midcrestal incision was performed after local anesthesia with 40 mL 4% articaine solution with adrenaline (Ubistesin, 3M ESPE, Seefeld, Germany). Care was taken to preserve keratinized mucosa. With the help of the elevator, a full-thickness buccal flap was carefully raised, and the vertical thickness of soft tissue was measured with a 1.0 mm marked periodontal probe (UNC, Hu-Friedy, Chicago, IL, USA). If the vertical soft tissue thickness was 2 mm or less, the tissue was considered thin (Group 1; Figure 1). If the mucosa thickness was more than 2 mm, it was considered thick (Group 2; Figure 2). After the measurement, the lingual full-thickness flap was elevated, and the site for implant placement was prepared. The implant bed was at least 1.5 mm from the adjacent tooth/teeth, and there was at least 1 mm of space between the buccal and lingual crests of the alveolar ridge and implant. Bone-level implants of 4.1 mm in diameter with platform-switched design (Institut Straumann AG, Basel, Switzerland) were placed level with the bone crest in a one-stage approach according to the manufacturer's recommendations (Figure 3). After insertion, healing abutments were connected, and flaps were closed without tension with 5/0 interrupted

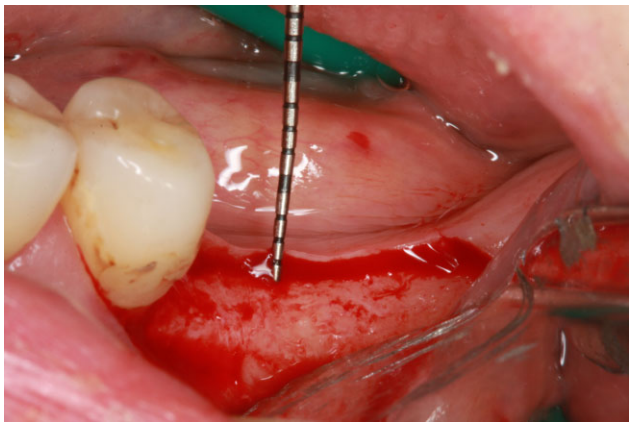

Figure 1 Implants in Group 1 were placed in thin crestal soft tissues (≤2 mm).

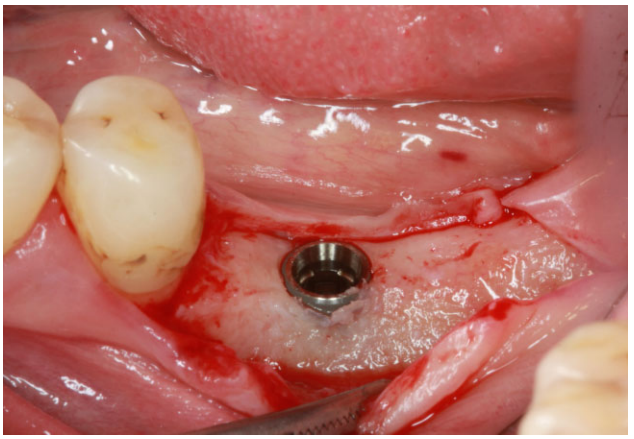

Figure 3 Bone-level implants were positioned equally with the crest according to manufacturer recommendations.

sutures (Assucryl, Assut Medical Sarl, Lausanne, Switzerland) (Figure 4). Patients in both groups were instructed to disinfect the operated site for 1 minute with 0.12% chlorhexidine digluconate rinse (Perio-aid, Dentaid, Barcelona, Spain) twice daily for one week. Patients were advised to avoid chewing on the operated site and to clean the healing abutments with a very soft toothbrush.

After 2 months of healing, the clinical stability of implants was evaluated. Implants were considered successfully osseointegrated if they were clinically immobile and showed no evident radiolucencies and the patients reported no pain.[21] All implants were restored with single screw-retained restorations by the same prosthodontist (T.L.) (Figure 5). After prosthetic treatment, the patients received individual oral hygiene instructions and were monitored in recalls every 6 months to ensure periodontal health (BOP < 20% and PI < 25%) was maintained throughout the study period.

Radiographic Examination

Radiographs were taken in high-resolution mode with a film holder, using the parallel technique. Intraoral radiographs were taken (1) after implant placement (baseline), (2) after 2 months of healing, (3) after insertion of the restoration, and (4) after 1-year follow-up post-reconstruction. This was performed for implants in both Group 1 (Figure 6) and Group 2 (Figure 7). Images were obtained in such a way that the implant-abutment interface and the threads would be clearly visible. If necessary, radiographs were taken repeatedly until the implant-bone interface was clearly measurable. Bone level measurements were performed by a blinded

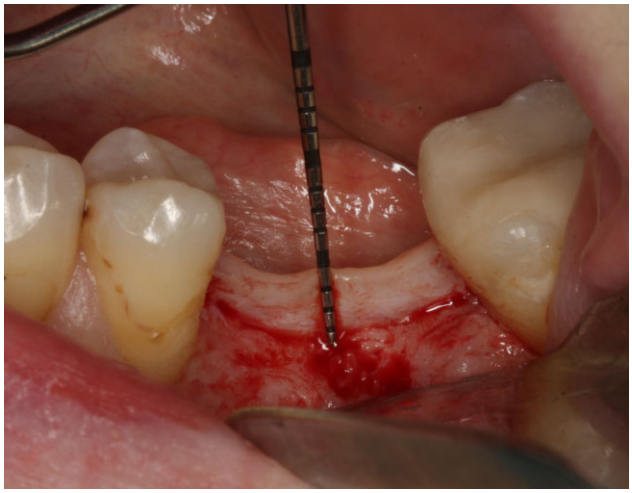

Figure 2 Implants in Group 2 were placed in thick crestal soft tissues (>2 mm).

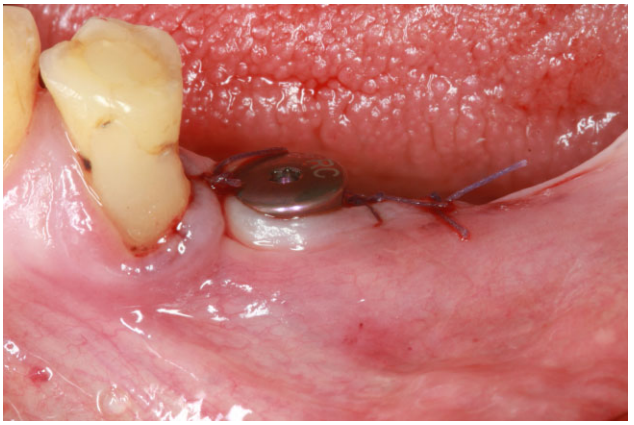

Figure 4 Healing abutments were connected to implants during one-stage surgery.

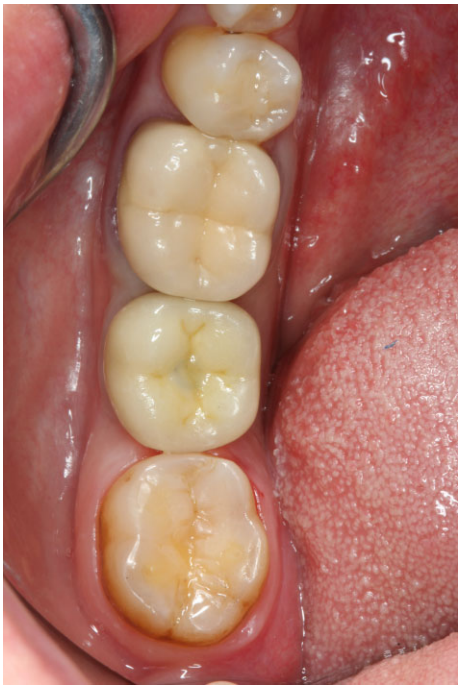

Figure 5 Implant in position 37 restored with screw-retained prosthesis.

examiner using a measurement software program (RVG Windows Trophy 7.0, Trophy Radiologie, Paris, France) at ×20 magnification. Before calculation of the crestal bone changes, RVG images were calibrated using the diameter of the implant (Figure 8). Bone loss in millimeters was calculated by comparing baseline radiographs with radiographs obtained during recall visits. The edge of the implant and first radiographic bone-implant contact were selected as the reference points for bone loss calculation. The mean of the mesial and distal measurements was recorded for the implant. The intraexaminer agreement was determined by the second and third measurements, which were performed 1 month apart. The mean difference between measurements did not exceed 0.1 mm, and the mean of three measurements was recorded.

Statistical Analysis

Data were analyzed using statistical software (SPSS 15.0 for Windows, SPSS Inc., Chicago, IL, USA), with the patient as a statistical unit. Descriptive statistics, including means, SEs, medians, and ranges of measurements, were calculated. The normality of the distribution was evaluated with the Kolmogorov-Smirnov test. As variables appeared to be non-parametric, the Mann-Whitney *U*-test was used to find differences between groups. Given the repeated calculations, multiple testing correction analysis was performed using two-way ANOVA. Later, lower and upper quartiles were calculated and data distributed into five groups according to bone loss extent – no loss, loss between 0.1 and 0.5 mm, loss of 0.51 to 1.00 mm, loss of 1.01 to 1.50 mm, and loss of more than 1.50 mm. The mean differences were considered statistically significant at $p \leq .05$ with a confidence level of 95%.

RESULTS

According to the sample size calculation, two equally sized groups with 40 individuals each were needed. Patients satisfying inclusion criteria were continuously screened until each group (thin and thick tissue) consisted of 40 patients with 40 implants. However, during the course of the study, it proved impossible to obtain parallel radiographs for one patient, who was therefore excluded. Three patients were excluded because implants did not achieve sufficient primary stability and required a submerged approach, and one patient did not

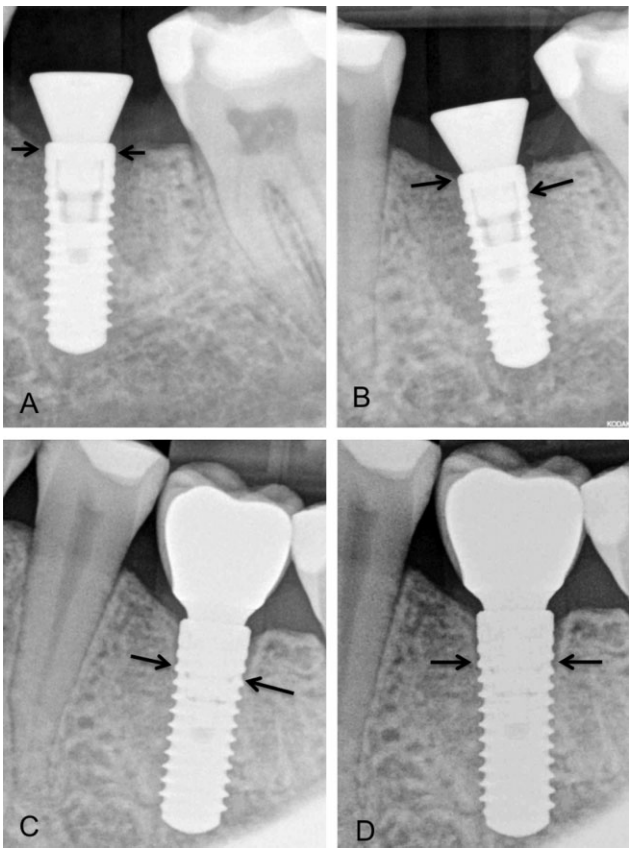

Figure 6 Crestal bone level after implant placement (A), 2 months after placement (B), after prosthetic restoration (C), and after 1-year follow-up (D) in Group 1 (thin soft tissues).

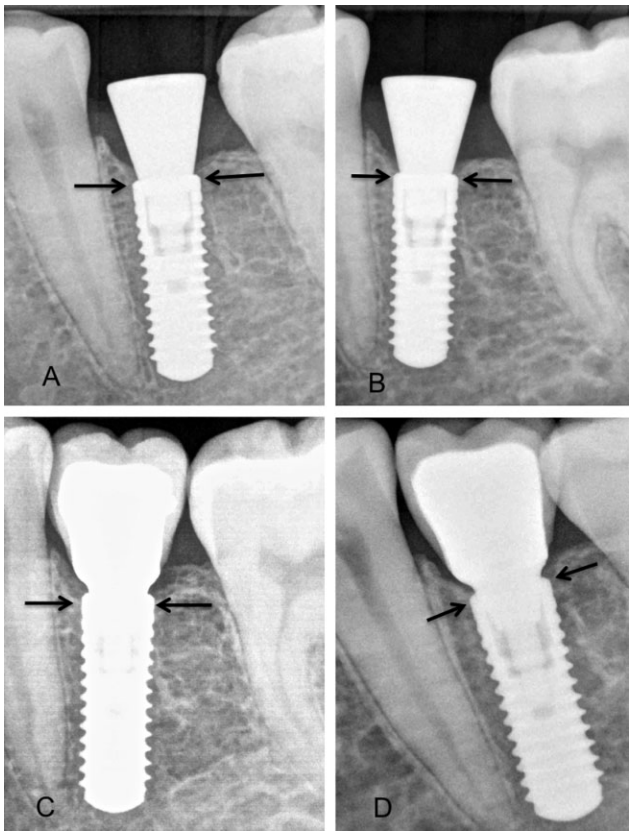

Figure 7 Crestal bone level after implant placement (A), 2 months after placement (B), after prosthetic restoration (C), and after 1-year follow-up (D) in Group 2 (thick soft tissue).

show up for follow-up visits due to change of residence. Therefore, additional patients were screened to replace the excluded individuals to maintain the size equality of the groups.

Thus, the final sample size included 80 patients (38 males and 42 females), on average 44 ± 3.34 years old (range 19 to 52). Implants were allocated to groups – 40 to Group 1, with thin tissue, and 40 to Group 2, with thick tissue. All 80 implants were restored with metal-ceramic screw-retained restorations. The implant survival rate after 1 year of function in both groups was 100%. No mechanical and/or biological complications were recorded at follow-up visits. Mean soft tissue thickness in Group 1 was 1.53 ± 0.07 mm (range 1.0–2.0 mm), while soft tissue thickness in Group 2 was 2.98 ± 0.03 mm (range 2.5–4.0 mm). This difference was statistically significant ($p < .001$). Crestal bone losses after 2 months and after 1 year are given in Table 1. After multiple testing correction, the general linear model analysis for univariate measures showed statistically significant differences between groups at all measurement time points (after 2 months, after prosthetic treatment, and after 1-year follow-up post-reconstruction; all $p < .001$). Table 2 shows the distribution of bone loss in both groups.

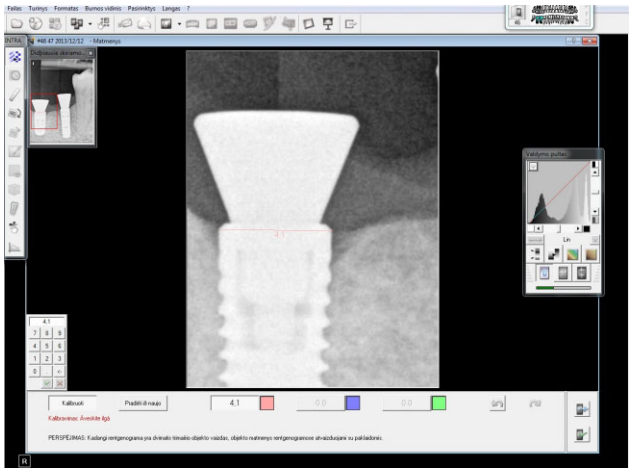

Figure 8 Calibration of the radiographic image based on implant diameter using measuring software.

TABLE 1 Crestal Bone Loss in Each Group

Group 1	Mean*	Max	Min	Median
After 2 months	0.76 mm	2.1	0.0	0.72
After restoration	0.97 mm	3.70	0.1	0.8
After 1 year	1.18 mm	2.1	0.1	1.2
Group 2	**Mean**	**Max**	**Min**	**Median**
After 2 months	0.17 mm	1.1	0.0	0.0
After restoration	0.21 mm	1.1	0.0	0.05
After 1 year	0.22 mm	1.1	0.0	0.00

*Statistically significant differences between thin and thick soft tissue groups were recorded at all measurement time points ($p = .001$).

DISCUSSION

This study aimed to evaluate the effect of platform switching on crestal bone maintenance in relation to soft tissue thickness. The results consistently showed that implants in sites with thin soft tissue showed significantly more bone loss compared with implants in sites with thick soft tissue. Based on this outcome, the null hypothesis was rejected.

This outcome is in agreement with a pilot study by Linkevicius and colleagues[15] that showed bone loss of 1.76 mm on average in thin tissue. Bone loss was less in the present study and reached up to 1.18 mm after 1-year follow-up. This difference may be related to the difference in implant design between the two studies.

TABLE 2 Distribution of Bone Loss in Each Group, *n* (%)

Bone Loss (mm)	After 2 Months	After Restoration	After 1 Year
Thin tissue			
0	3 (7.5)	1 (2.5)	0 (0)
0.1–0.5	9 (22.5)	4 (10)	2 (5)
0.51–1.0	19 (47.5)	27 (67.5)	11 (27.5)
1.01–1.5	3 (7.5)	3 (7.5)	11 (27.5)
>1.5	6 (15)	5 (12.5)	16 (40)
Thick tissue			
0	24 (60)	20 (50)	20 (50)
0.1–0.5	12 (30)	14 (35)	14 (35)
0.51–1.0	3 (7.5)	5 (12.5)	5 (12.5)
1.01–1.5	1 (2.5)	1 (2.5)	1 (2.5)
>1.5	0 (0)	0 (0)	0 (0)

Implants in the pilot study had a platform size of 0.7 mm and flaring necks,[15] while the present study used implants with a platform of 0.4 mm and parallel necks. It has been suggested that the degree of the implant-abutment size mismatch in platform switching might be important for the amount of crestal bone loss.[22] While the small sample size in the study by Linkevicius and colleagues[15] precluded definite conclusions, the results of the current trial with 40 patients and 80 implants justify the statement that implants with platform switching do not perform well in reduction of bone loss in thin soft tissue. This inability of platform-switched implants to retain bone better than conventional implants has also been observed by other authors. Enkling and colleagues[16] could not confirm the hypothesis of reduced peri-implant bone loss for platform-switched implants in a randomized controlled clinical trial. Other clinical trials have reported diverse measurements of bone loss. For example, Vela-Nebot and colleagues[18] reported significantly less bone loss around platform-switched implants compared with a control group. However, bone loss ranging from 0.3 to 1.3 mm was observed around some implants in the test group, with mean bone loss calculated to be 0.77 mm. Vela-Nebot and colleagues did not give an explanation for such a wide spread of results, although their results suggest the influence of additional factors, such as patient individualities or statistical dispersion. It can be speculated that different thicknesses of soft tissue may have been present in different patients. Interestingly, dog studies do not confirm an advantage for platform switching in bone level preservation.[23,24] It is known that the thin biotype is more prevalent in dog mucosa,[11,25] which is supportive of the idea that bone loss around platform-switched implants occurs due to formation of biological width. A recent comparative split-mouth study by Vervaeke and colleagues[26] has also shown more bone loss when soft tissue is thin, confirming the data described in the present paper.

It is interesting to note that almost 85% of the implants in thick mucosal tissue showed no bone loss or a loss no more than 0.5 mm after 1-year follow-up. In contrast, almost 70% of implants in thin soft tissue showed more than 1.00 mm of bone loss after 1-year follow-up. This demonstrates the influence of soft tissue thickness on the degree of crestal bone remodeling.

During the past decade, most published papers on platform switching, with a few exceptions, did not evaluate tissue thickness at the time of implant placement.[1–3,18,19,22,27–39] Canullo and Rasperini[3] differentiated thick and thin biotypes; however, this differentiation could not be considered reliable, as it was based on postrestorative probing around implant restorations, and therefore, no information about the pretreatment condition of the soft tissue was presented. Likewise, Enkling and colleagues[16] mentioned that implants were positioned in medium or thick soft tissue; however, they did not describe how the mucosa was measured or what tissue thickness was considered to be "medium" or "thick." In fact, there has been just one study[40] that evaluated initial crestal soft tissue thickness before placement of platform-switched implants; these were placed in soft tissue with a thickness of ≥2 mm, and after 2 years of follow-up, bone loss was 0.47 mm. It is tempting to say that all previous

studies on platform switching overlooked the factor of soft tissue thickness. The initial thickness of mucosa appears to be important, as bone loss after 1 year may vary from 0.3 mm to 1.3 mm, as in the previously discussed study by Vela-Neblot and colleagues,[18] or from 0.2 mm to 1.17 mm, as in the present study. The authors of the present study intentionally calculated a mean bone loss for all implants without regard to soft tissue thickness. This mean bone loss would be 0.71 mm; however, this outcome does not account for the causes of bone loss. The best results were achieved for implants in sites with thick mucosal tissue (Group 2), where only 0.21 mm of bone loss was reported. This outcome is similar to that of Prosper and colleagues'[2] study reporting almost no bone loss 24 months following placement in implants with platform switching (0.04 ± 0.22 mm) compared with control implants with regular abutments (0.27 ± 0.46 mm).

Initial soft tissue thickness is important for the formation of biological width around implants. It has been shown in animal and clinical studies that thin vertical soft tissue is associated with bone loss during morphogenesis of peri-implant mucosa.[41–43] A recent experimental human study investigated mucosal biopsies and showed that at 8 weeks, the soft tissue was about 3.6 mm thick, consisting of a barrier epithelium of 1.9 mm and a connective tissue portion of 1.7 mm.[44] This finding suggests that the bone undergoes remodeling to create sufficient space for a peri-implant seal to be formed. A similar conclusion was reached by Vandeweghe and De Bruyn,[20] who performed a within-implant evaluation of the platform switching concept and found that platform switching was effective only in those cases where peri-implant mucosa was thick.

The present study has several limitations. The validity of the results might be limited to the posterior mandibular area, and additional studies may be required to evaluate the effect of soft tissue thickness on crestal bone stability in the maxilla. On the other hand, this study shows proof of concept that thin soft tissue may predispose bone to significant remodeling around implants with platform switching.

CONCLUSION

Within the previously mentioned limitations of the study, it can be concluded that vertical soft tissue thickness plays a major part in the etiology of early crestal bone loss. Use of implants with platform switching did not preserve crestal bone if, at the time of implant placement, mucosal tissues were thin. Conversely, in thick soft tissue, the use of platform switching maintained bone with minimal remodeling.

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