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The influence of submerged healing abutment or subcrestal implant placement on soft tissue thickness and crestal bone stability. A 2-year randomized clinical trial

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Abstract

Purpose: Aims of the study were: (a) to register crestal bone loss around 1.5 mm subcrestally placed implants and epicrestally placed implants with soft tissue tenting technique, (b) to record bone remodeling in subcrestal group, and (c) to determine the increase of vertical soft tissues after tenting.

Materials and methods: Thirty-two patients with vertically thin tissues of 2 mm or less received 40 submerged bone level platform-switched implants, divided into two groups—(a) 1.5 mm subcrestally placed implants and (b) epicrestally placed implants with soft tissue tenting over 2 mm healing abutments. At the second stage surgery, implants received 4 mm healing abutments, soft tissue thickness was measured in epicrestal group, and later implants were restored with zirconia-based screw-retained single restorations. Radiological images were taken at the second stage surgery, restoration delivery and after 2 years of follow-up. Bone loss was calculated as a distance between implant neck and first radiographically visible bone-to-implant contact. Bone remodeling was calculated as a distance between the bone crest and implant neck. Mann-Whitney *U* test was used for statistical analysis, significance set to 0.05.

Results: After 2 years of follow-up, Group 1 (subcrestal) had 0.18 ± 0.32 mm of bone loss, Group 2 (epicrestal with 2 mm healing abutment) had 0.51 ± 0.4 mm of bone loss, with statistically significant difference ($P = .001$). Bone remodeling in Group 1 (subcrestal) was 1.17 ± 0.51 mm. Vertical tissue thickness in epicrestal group before the intervention was 1.85 ± 0.26 and 3.65 ± 0.41 mm after the use of 2 mm healing abutment, with a statistical difference ($P = .005$).

Conclusion: Subcrestal implant placement can significantly reduce crestal bone loss, compared to vertical soft tissue thickening by tenting of epicrestally placed implants, although soft tissue tenting can significantly increase soft tissue thickness.

1 | INTRODUCTION

Vertical soft tissue thickness, as a factor for marginal bone stability, faced extensive research in the last decades. Although first brought

up by Berglund and Lindhe in an animal experiment, real attention of clinicians to the subject was drawn by Linkevicius et al studies, which showed that if vertical soft tissues on the crest of the alveolar ridge are 2 mm or less at the time of implant placement, implants, regardless

of the design, will undergo unavoidable bone resorption by establishing sufficient biologic protection. Later, these findings were confirmed by other research teams from different centers.

Conclusively, the question arises, what strategies could be used to increase vertical soft tissue thickness, if such condition is diagnosed. Vertical soft tissue augmentation with soft tissue graft substitutes was suggested by the authors. This procedure resulted in higher soft tissue thickness; therefore, development of biological width proceeded already in adequate mucosal environment, eventually improving marginal bone stability.

Another option was proposed by Vervaeke et al, who were the first to describe subcrestal implant placement as a method to accommodate the problem of thin soft tissues. The authors reported that subcrestally placed implants had only 0.04 mm bone loss, while control group implants, which were placed epicrestally, experienced 0.72 mm of bone resorption due to inadequate crestal soft tissue thickness. Novel it might be, Vervaeke et al study did not address the bone above the neck of subcrestally placed implants, since bone changes were measured apically only from implant/abutment connection. Subcrestal implant position results in a unique situation, when the bone above the implant neck is available, and differs from an implant placed epicrestally, when only soft tissues cover the top of the implant. In addition, subcrestal implant placement requires sufficient bone height to house a deeply positioned implant, and that is not always possible due to endangering of anatomical structures.

This brings us to the third method, which suggests to increase soft tissue thickness by positioning and suturing soft peri-implant tissues over 2 mm height healing abutment, connected to epicrestally placed implant, sometimes referred to as tenting technique.

This method indeed requires scientific appraisal, as there are no reliable data being effective.

Therefore, the aims of this clinical study were 3-fold: (a) to register crestal bone loss around 1.5 mm subcrestally placed implants and epicrestally placed implants with 2 mm healing abutments; (b) to register bone remodeling (bone changes above implant neck) in subcrestal group; and (c) to determine how vertical soft tissue has increased in epicrestal group, compared to the initial situation.

Null hypothesis was raised that subcrestal implant positioning does not reduce crestal bone changes below the implant neck.

2 | MATERIALS AND METHODS

2.1 | Study design and population

The present study was a randomized parallel-group prospective clinical trial, which protocol was reviewed and approved by the local University ethical committee (BEC-LSMU(R)-36). The study took place from 2016 to 2019 and was conducted according to the principles of Helsinki Declaration, following CONSORT guidelines for clinical trials. Patients were recruited in private practice office. The main inclusion factor was vertical soft tissue thickness being ≤ 2 mm in the posterior mandible area. Additional inclusion criteria were: (a)

no less than 18 years of age, (b) generally healthy patients with no medical contraindication for implant surgery, (c) missing teeth in lower jaw posterior molar area, (d) minimum of 6 mm bone width, (e) healthy soft tissue (BOP < 15%, PI < 15% CPITN < 2), (f) minimum 4 mm keratinized gingiva buccally and lingually, (g) no bone augmentation procedures before and during implant placement, and (h) signed informed consent form for participation and permission to use obtained data for research purposes. Exclusion criteria were as follows: (a) smokers (≥ 10 cigarettes $^{-1}$ day $^{-1}$), (b) systemic diseases, (c) drugs, influencing healing, (d) poor oral hygiene, (e) alcoholism and drug addiction, (f) uncontrolled periodontitis, and (g) pregnant or lactating women.

2.2 | Study groups and randomization

In Group 1, implants were placed 1.5 mm subcrestally, and in Group 2, implants were positioned at the level of the bone with 2 mm height healing abutments, which were covered with released mucoperiosteal flaps and sutured. The generation of the random allocation sequence was performed by computer software. Randomization of the patients was performed by sealed envelope drawings, which were opened after flap elevation just before implant placement.

2.3 | Outcome measures

Crestal bone loss was designed as the primary outcome measure of the study and was measured on standardized parallel apical radiographs. Secondary outcome measures included bone remodeling, determined in the same way, while vertical soft tissue thickness, pocket-probing depth (PPD), bleeding on probing (BOP), and plaque index (PI) were measured clinically.

2.4 | Surgical procedures

Before surgical intervention, patients were asked to rinse for 1 minute with a 0.12% chlorhexidine solution (Perio-Aid, Dentaids). Local anesthetic 4% articaine 40 mL solution with adrenaline (Ubistesin, 3 M ESPE) was used for local infiltration of the tissues. After sufficient numbness, midcrestal incision of the implant placement site was performed. The full-thickness buccal flap was raised without touching the lingual flap and vertical soft tissue thickness is assessed with a periodontal probe with a 0.5 mm step (UNC, Hu-Friedy). The probe was positioned in an upright position to the bone crest in the center of the future implant placement. Patients that are included in the study need to have a tissue thickness of ≤ 2 mm (Figure 1). At this stage of intervention, randomization was performed to allocate the patients to Group 1 (subcrestal) or Group 2 (epicrestal) fractions. Before placing the implant, bone smoothening was performed to level the implantation site, if alveolar ridge was uneven.

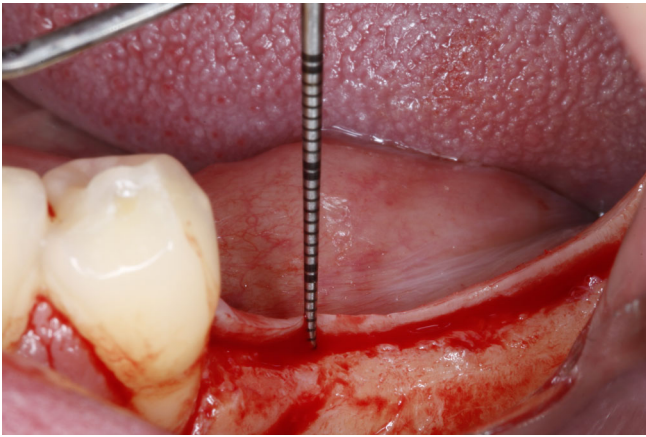


FIGURE 1 Initial measurement of vertical soft tissue thickness with 0.5 mm graded periodontal probe had to be ≤ 2 mm to be included into the study

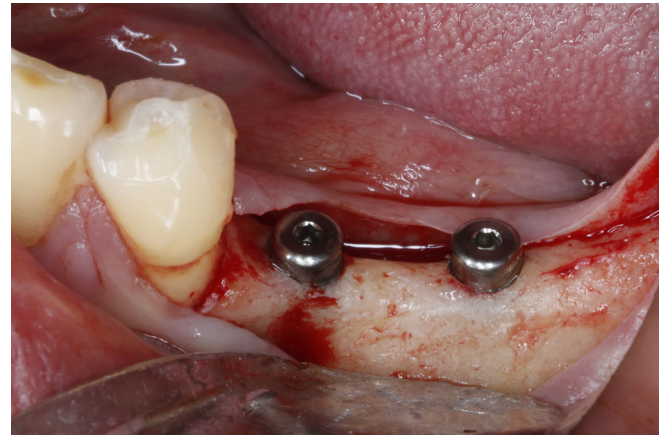


FIGURE 3 Epicrestally placed implants with 2 mm height healing abutments to be tented with released mucoperiosteal flaps

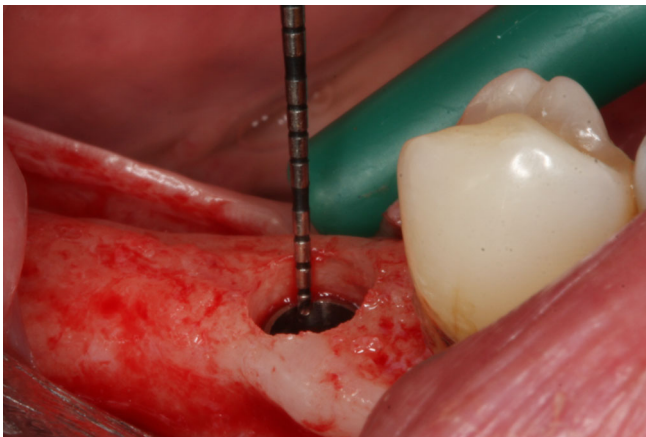


FIGURE 2 Subcrestal implant position 1.5 mm below the bone level in Group 1

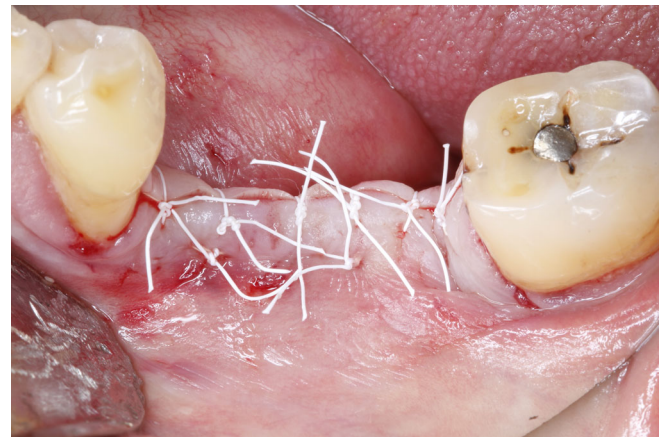


FIGURE 4 Two-layer suturing technique of the tenting method in Group 2. Note deep matrix sutures for tissue elevation and simple interrupted sutures

2.5 | Subcrestal group (Group 1)

After marking the insertion position with a sharp pilot drill, the implant bed was prepared. The implant was placed 1.5 mm below the bone, as the exact position was secured by drilling one-step longer drill, compared to the implant placed (Figure 2). The drills had drilling stops, which allowed the implant to be placed precisely. Bone level implants with platform switching and 7.5° conical connection was placed (Conelog, Camlog Biotechnologies GmbH). A cover screw dipped in 0.12% chlorhexidine gel (Perio-Aid Gel, Dentaïd) was placed and the flap was closed with 6/0 polypropylene monofilament (Prolene, Ethicon) sutures. Patients were instructed to rinse the operated site with 0.12% chlorhexidine-digluconate (Perio-Aid; Dentaïd) solution twice a day for a week and prescribed 0.5 g of amoxicillin (Ospamox, Biochemie) three times daily for 5 days. The sutures were removed after 10 days post-surgery. The second stage operation was performed 2 months after implant placement. Under anesthesia, full-thickness flaps were raised and implants were uncovered, carefully removing

the bone above if needed. Four millimeter height healing abutments were connected, and tissues sutured with 6/0 polypropylene monofilament (Prolene, Ethicon). Sutures were removed after 10 days post-surgery.

2.6 | Epicrestal group with tenting (Group 2)

Implants in this group were placed equally with bone crest and immediately 2 mm height healing abutment was attached. Then full-thickness buccal and lingual flaps were released to achieve easy advancement of the soft tissues to cover 2 mm healing (Figure 3). First, deep matrix sutures were used to approximate the flaps closer together and then simple interrupted sutures were made to close the flaps without tension (Figure 4). Patients were instructed to rinse the operated site with 0.12% chlorhexidine-digluconate (Perio-Aid; Dentaïd) solution twice a day for a week and prescribed 0.5 g of amoxicillin (Ospamox, Biochemie) three times daily for 5 days. The

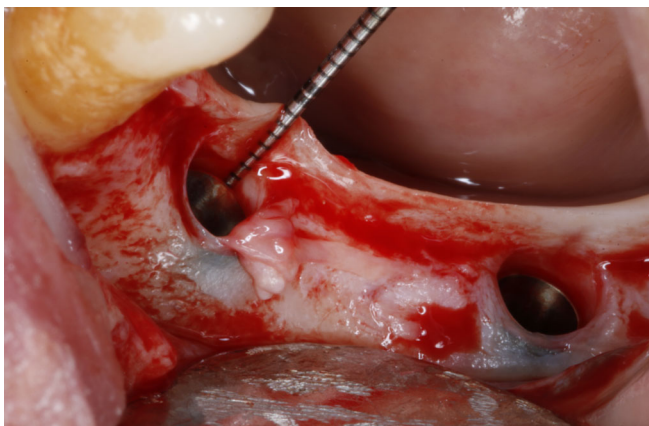


FIGURE 5 Measurement of vertical soft tissue thickness in Group 2 during implant uncovering. Note the thicker tissues up to 3.65 mm, which was statistically larger compared to baseline



FIGURE 6 Healing abutments of 4 mm height connected to epicrestal implants

sutures were removed after 10 days. Healing continued 2 months, until implant uncovering was performed. Following the incision at implant placement, a buccal flap is raised, leaving the lingual tissue untouched. The assessment of vertical soft tissue thickness was performed in a previously described manner (Figure 5) Healing abutments of 4 mm in height were connected and the flap is sutured by 6/0 polypropylene monofilament (Prolene, Ethicon) (Figure 6). Sutures were removed after 10 days post-surgery.

2.7 | Restorative procedures

One-month-post second stage surgery, when peri-implant tissues showed complete healing, patients was directed to prosthetic rehabilitation. All implants were restored with single implant-supported crowns. Titanium bases of 0.8 mm gingival height were selected as supporting interface for zirconium oxide base (Katana Zirconia, Kuraray Noritake), which was veneered with lithium disilicate restorations (IPS e.max, Ivoclar Vivadent), using soldering procedure with



FIGURE 7 Single screw-retained zirconia-based implant restorations supported by low titanium bases was used to restore all implants

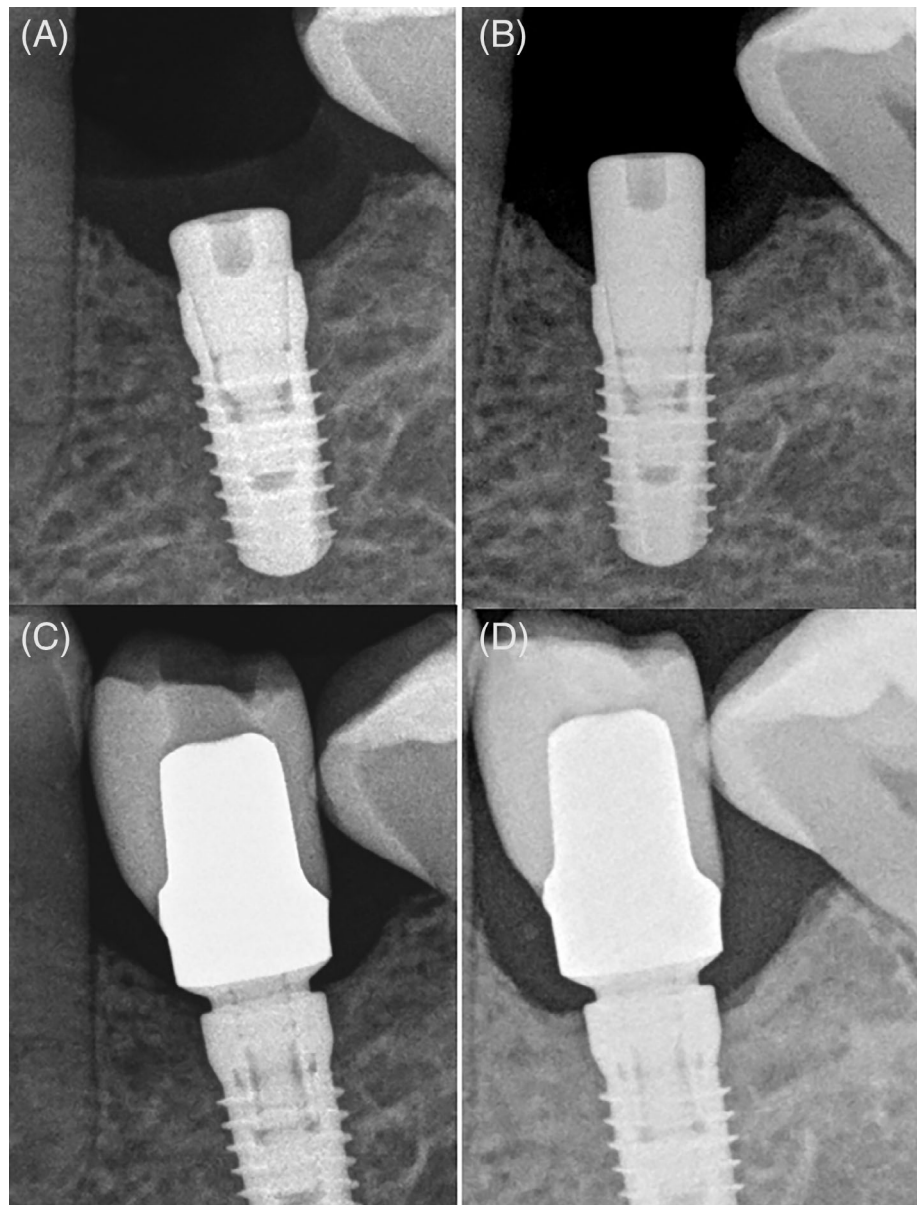
fusing material (Hotbond, Kuss Dental SL). Finished restorations were cemented to titanium interfaces with resin cement (G-CEM LinkAce; GC) (Figure 7).

Screw-retained crowns were steamed for 5 seconds at 4 MPa (VAP1; Zhermark) and cleaned in an ultrasonic bath (Pro-sonic 300, Sultan Healthcare), in a 10% mixture of distilled water and detergent (Siladent, Dr. Bohme & Schops GmbH) for 10 minutes. Then, restorations were carefully screwed to implants until torque of 35 N cm^{-1} was reached. Screw access hole was firmly compacted with autoclaved PTFE tape, leaving at least 2 mm space for the insertion of filling material. Then, the screw access hole of the restoration was etched with 9.6% hydrofluoric acid (Pulpdent Corporation, Watertown) for 10 seconds, and adhesive with silane (Clearfil Universal Bond Quick, Kuraray Noritake) was applied and air-dried. Then, a layer of light-cured composite (Gradia Posterior, GC) was inserted to fill the space and light-cured for 40 seconds. Post prosthetic treatment, the patients received individual oral hygiene instructions and were monitored in recalls every 6 months to ensure periodontal health was maintained throughout the study period.

2.8 | Radiographic analysis

Intraoral radiographs were performed and evaluated in each patient during the study: (a) after second stage implant surgery; (b) after delivery of the restoration; and (c) after 2-year follow-up. A digital film holder and individual bite blocks were used to ensure reproducible parallel radiographic images. In addition, the images were obtained in the way that non-distorted implant/abutment interface and implant threads would be clearly visible, as this confirms that the radiographic image is parallel (Figures 8 and 9). Radiological evaluation and measurements were performed using RVG Windows Trophy 7.0 software measurement program with a magnification (20 \times) by one examiner, which was not familiar with the study. The calibration of RVG images was performed using an implant diameter of 3.8 as a reference point. Two different types of bone changes were calculated. Bone loss was

FIGURE 8 Crestal bone stability in Group 2. A, Implant placement with 2 mm healing abutment. B, 1 month after implant uncovering and connection of 4 mm healing abutment (T1); C, Restoration delivery (T2); D, 2-year follow-up (T3) [Corrections added on 22 June 2020 after first publication: panel D in Figure 8 has been corrected.]



calculated as a distance between implant neck and first radiographically visible bone-to-implant contact and measured in both groups. Bone remodeling was calculated as a distance between the bone crest and implant neck only for the subcrestal implant group, as implant position indicates that there is bone above the implant neck after placement (Figure 10). The mean of the mesial and distal measurements was recorded for the implant.

2.9 | Clinical evaluation

The increase of vertical soft tissue thickness in Group 2 was measured by comparing soft tissue thickness at the time of implant placement and after the second stage surgery in the exact same spot (Figures 1 and 5).

Peri-implant soft tissue parameters and restorations were registered at 2 years follow-up (Figure 11). PPD measured from the mucosal margin to the bottom of the pocket in millimeters. The

measurements were performed in four sites—mesiobuccal, distobuccal, mesiolingual, and distolingual and the mean value of all sites were reported. Presence or absence of BOP was calculated in percentage of total probed sites. PI was scored from 0 to 3. 0—no plaque. 1—a film of plaque adhering to the free gingival margin and adjacent area of the tooth; 2—moderate accumulation of soft deposits within the gingival pocket, or the tooth and gingival margin, which can be seen with the naked eye; and 3—an abundance of soft matter within the gingival pocket and/or on the tooth and gingival margin. The mean of PI around all implant restorations will be calculated.

2.10 | Statistical analysis

The sample size was determined using G*Power v 3.1.9.2. Software. Previous clinical studies on the subject were taken into account as an example type I error rate of $\alpha = .05$ was set. To achieve a power of at

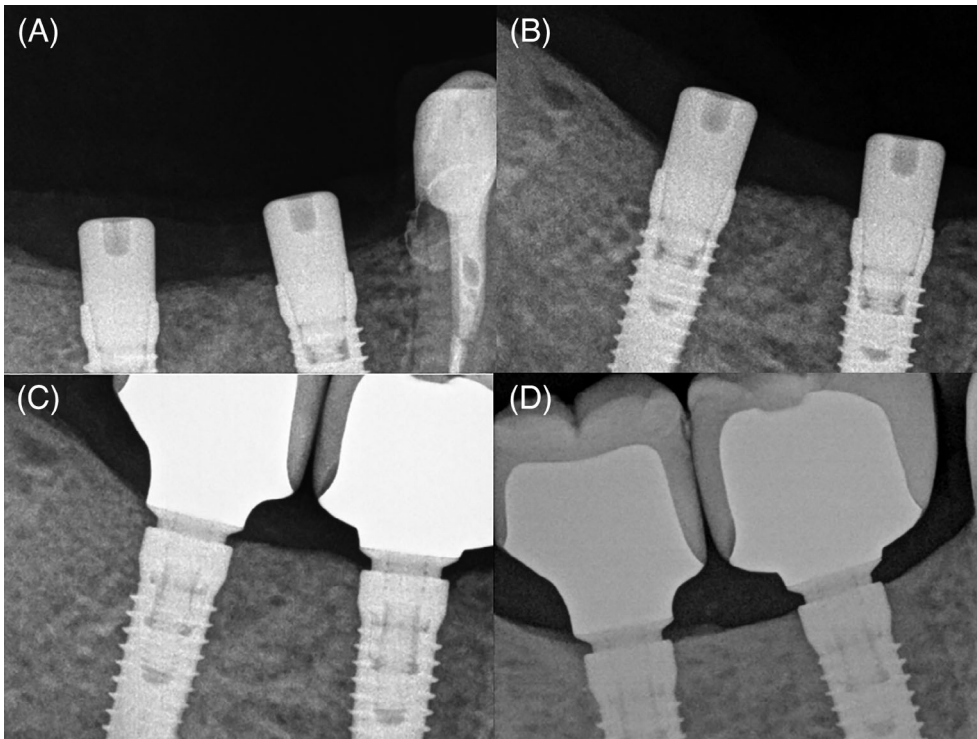


FIGURE 9 Crestal bone loss and remodeling in Group 1. A, Implant uncovering and connection of 4 mm healing abutment. B, 1-month post-implant uncovering and connection of 4 mm healing abutment (T1); C, Restoration delivery (T2); D, 2-year follow-up (T3) [Corrections added on 22 June 2020 after first publication: panel D in Figure 9 has been corrected.]

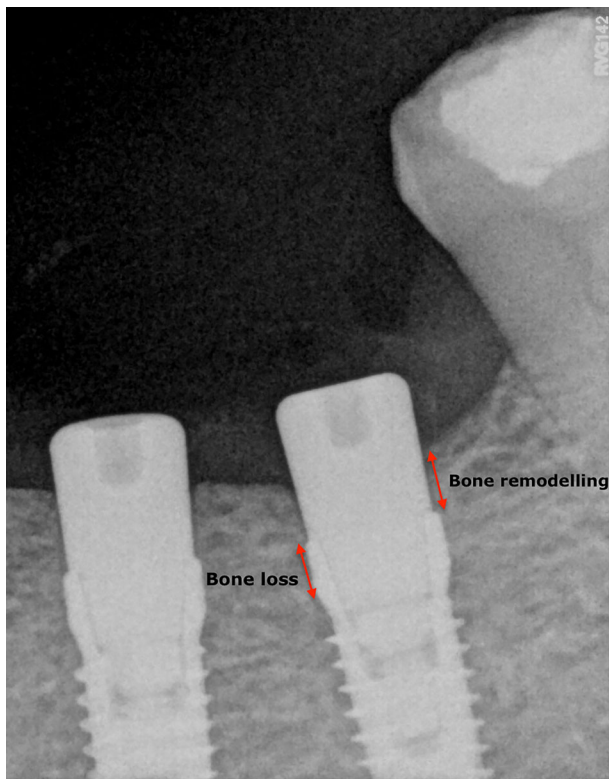


FIGURE 10 The difference between crestal bone loss and crestal bone remodeling. Bone loss was calculated as a distance between implant neck and first radiographically visible bone-to-implant contact and it was measured in both groups. Bone remodeling was calculated as a distance between the bone crest and implant neck only for subcrestal implant group



FIGURE 11 Restoration at the time of 2-year follow-up evaluation

least 80%, under the aforementioned assumptions, a sample size of 18 was determined, which was increased to 20 to accommodate possible dropouts, combining usually about 10% of the included patients.

Statistical analysis was performed using IBM SPSS Statistics v20 software. Outcome measures were described by means, SDs, SEM, medians, and minimum and maximum values. To determine the normality of data distribution, the Shapiro-Wilk test was used ($\alpha = .05$). Homogeneity of variance was confirmed by Levene's test ($P > .05$). The mean differences were considered statistically significant at $P \leq .05$ with a confidence interval of 95%. Depending on the distribution, several

TABLE 1 Statistical analysis of crestal bone loss (mm) and differences between the groups at different time points

Descriptive statistics										
Time point	Group	N	Mean	SD	SE	Median	Min	Max	IQR	Difference between groups
T1	Epicrestal	20	0.12	0.14	0.04	0.06	0	0.35	0.3	0.059
	Subcrestal	20	0.04	0.09	0.02	0	0	0.3	0	
T2	Epicrestal	20	0.43	0.34	0.8	0.38	0	1.28	0.43	<0.0001
	Subcrestal	20	0.11	0.27	0.58	0	0	1.19	1.13	
T3	Epicrestal	20	0.51	0.4	0.1	0.35	0	1.32	0.45	<0.0001
	Subcrestal	20	0.18	0.32	0.06	0.06	0	1.15	0.22	

Bold values show statistical significance. Significant when $P \leq .05$.

^aMann-Whitney U test.

TABLE 2 Descriptive statistics of bone remodeling (bone changes above the implant neck) in subcrestal group

Time point	N	Mean	SD	SE	Median	Min	Max	IQR
T1	20	0.6	0.34	0.08	0.61	0.08	1.17	0.59
T2	20	1.07	0.39	0.09	1.04	0.21	1.87	0.42
T3	20	1.17	0.51	0.1	1.15	0.2	2.27	0.61

TABLE 3 Analysis of bone loss between different time points in both groups and bone remodeling in subcrestal group

Wilcoxon Signed-Rank Test	Bone loss between different time points		Remodelation in subcrestal group	
	P		Paired samples t -test	P
	Epicrestal	Subcrestal		
T1-T2	.003	.285	T1-T2	.001
T1-T3	.006	.028	T1-T3	.001
T2-T3	.955	.092	T2-T3	.009

Bold values show statistical significance. Significant when $P \leq .05$.

statistical tests would be applied. In case of parametric distribution, T -test would be used to detect differences between groups, if nonparametric, the Mann-Whitney U test will be used. Analysis of bone loss between different time points in each group was done using the Wilcoxon Signed-Rank test. The α error will be set at .05. Implant was used as a statistical unit. An independent blinded examiner did the analysis of the bone loss and was not informed about the aim of the study.

3 | RESULTS

Thirty-two patients (19 male and 13 female, mean age 45.4 \pm 2.2 years, range from 21 to 55 years) met the inclusion criteria and were treated in the study. They received 40 submerged bone level platform-switched implants with a 7.5° conical implant/abutment connection (Conelog, Camlog Biotechnologies GmbH). All implants integrated and were restored with single screw-retained restorations. No dropouts were registered; therefore, 40 implants were available for evaluation after 2 years follow-up.

Initial statistical analysis revealed that bone loss data distribution in both groups was heterogeneous (Shapiro-Wilk test, $P < .05$). The

difference between groups in crestal bone loss was evaluated using the Mann-Whitney U test. After the second stage surgery (T1), bone loss between both groups was insignificant ($P = .059$). However, after loading (T2) and after 2 years (T3) the difference in crestal bone loss between subcrestal and epicrestal groups was statistically significant ($P < .0001$) (Table 1).

Descriptive statistics of bone remodeling in subcrestal group is presented in Table 2.

Analysis of bone loss between different time points (T1, T2, and T3) in both groups was done using the Wilcoxon Signed-Rank test and paired samples T -test was employed to detect between all three time points regarding bone remodeling around subcrestally placed implants (Table 3).

Vertical tissue thickness in epicrestal group before the intervention was 1.85 and 3.65 mm after the use of 2 mm healing abutment, with a statistical difference ($P = .005$) (Table 4).

Premature exposure of tented 2 mm healing abutments was registered in two patients (three implants).

Distribution of PD data was homogenous (Shapiro-Wilk test for both groups $P > .05$), while data for BOP and PI were heterogeneously distributed (Shapiro-Wilk test for both groups $P < .05$). Thus, PD was

TABLE 4 Vertical soft tissue thickness before and after soft tissue augmentation by tenting procedure

	Mean	SD	SE	Median	Min	Max	<i>p</i>
Before	1.85	0.26	0.08	2.50	2.00	2.50	.05
After	3.65	0.41	0.13	3.75	3.00	4.00	

Difference between groups compared using Wilcoxon Signed-Rank Test. Significance level 0.05.

^aStatistically significant difference.

TABLE 5 No statistical differences were found between the groups in regards to plaque index, bleeding on probing, and probing depth

	Epicrestal	Subcrestal	<i>p</i>
PI	0.15 (SD = 0.31; range 0-1)	0.18 (SD = 0.37; range 1-1.25)	0.745
BOP	0.19 (SD = 0.28; range 0-1)	0.11 (SD = 0.24; range 0-0.75)	0.137
PD (mm)	2.46 (SD = 0.94; range 0.75-5.25)	2.74 (SD = 0.75; range 1.5-4)	0.532

^aMann-Whitney *U* test.

^bIndependent samples *T*-test.

analyzed using independent samples *T*-test and Mann-Whitney *U* test was employed for PI and BOP. No statistical differences between two groups in regards to PI, bleeding on probing, and probing depth (Table 5).

4 | DISCUSSION

This study evaluated crestal bone stability in two methods of thin soft tissue enhancement—subcrestal implants placement and submerging of 2 mm healing abutment. The results have shown that significantly less bone loss occurred around subcrestally inserted implants, thus based on this, the null hypothesis was rejected.

The outcome is in agreement with the 2-year clinical study by Vervaeke et al, which showed only 0.04 mm of bone loss around subcrestally placed implants with platform switching and conical connection. It can be concluded that placing implants below the bone level is the verified method to compensate initially thin crestal soft tissues.

Several implant design factors might be listed as reasons in the development of crestal bone stability. Implants used in the current study did not have any polished neck. It was proved by Hammerle a few decades ago that polished implant surface does not integrate and cause bone die-back. This is supported by newer studies, claiming the same outcome. Implant-abutment connection microgap is obviously important in crestal bone loss progression, and if located close to the bone level, might cause bone resorption in flat-to-flat connections. Therefore, implants with platform switching, which microgap is shifted inward horizontally from bone margin, were advised to use to decrease bacterial leakage. In addition to that the stability of implant-abutment connection seems to be important, especially if the implant

is placed subcrestally. It was reported that implants with steep conical connection positioned 1.5 mm subcrestally had only minor bone loss of 0.2 mm after 1 and 3 years follow-up, while implants with the conical connection of 45° seem to have bone loss up to 0.7 mm. Of course, connection stability is not an ultimate factor, as low levels of bone loss have been reported around implants with simple internal hexagon. However, the subcrestal implant position produces a different environment, possibly more sensitive to any micro-movements of abutment connection; thus, the need of stable junction is more relevant. It can be suggested that the deeper the implant is placed in the bone, the more connection stability is relevant.

It should be stressed that subcrestal implant positioning is different from epicrestal or supracrestal positions, as the bone is present above the implant neck. This bone portion undergoes changes, but that is not evaluated in previous studies. For example, Vervaeke et al report that subcrestal implant bone loss was 0.04 mm, however, does not discuss bone changes above the implant neck, which are obvious in presented radiographic images. In order to the clear which bone portion is discussed, it might be suggested to differentiate bone remodeling from bone loss (Figure 11). Bone remodeling could be addressed as bone resorption above the implant neck and is restricted to subcrestally placed implants, as only those have bone present above the collars after placement. This indicates that bone loss is the process of bone resorption, which exposes the implant neck. Although both processes involve bone changes, their importance to implant success is different. It can be suggested that bone remodeling is not harmful to subcrestal implants, as the bone resorbs to the connection level and stops. This is a biological process of how soft tissue height elongation at the expense of the bone. Therefore, the current study has reported bone remodeling to be around 1.2 mm in the subcrestal group, indicating that soft tissues increased on that number. It is interesting to note that implants were placed 1.5 mm below the bone level, indicating that not all bones were remodeled.

It is obvious that bone loss, or bone changes, which expose the neck of the implant with a rough surface is far more dangerous than bone remodeling. The current study reported that bone loss in the subcrestal group was 0.11 mm, very similar to 0.04 mm, reported in other studies with subcrestal implant placement. It could be hypothesized that after initial bone remodeling of bone above the implant neck, the vertical soft tissue thickness was improved, and that stopped further bone reaction, thus almost no bone loss was recorded.

On the contrary, the group of epicrestal implant placement with 2 mm healing abutment and using simultaneous soft tissue tenting showed 0.33 mm more bone loss, which was significantly larger than in the subcrestal group. This could be explained as this procedure involves additional risks, like perforation of the mucosa with gingival formers.

Prosthetic treatment included using 0.8 mm gingival height titanium bases in both groups not to introduce additional co-founding factor. It has been reported in the literature that the abutment should have at least 2 mm gingival height to prevent bone loss. Blanco et al have shown 0.83 mm of crestal bone loss with 1 mm abutment height,

compared to only 0.18 of bone loss, if abutment gingival height was 3 mm. However, results of the current study contradict this current data, as subcrestal group implants had only 0.18 mm of bone loss, although titanium bases were even shorter than 1 mm. It could be added that the gingival height of titanium base is probably more important for bone remodeling process than bone loss. **The use of a 0.8 mm short gingival titanium base inevitably results in the steep emergence profile of the restoration, and it was shown by Katafuchi et al that if the bone level implant's emergence angle was >30°, there was a significantly more bone resorption.** It can be hypothesized that the restoration with a short base has exerted additional pressure on supra-implant bone, therefore causing additional remodeling on the bone. This can be supported by the fact that after the second-stage surgery bone remodeling was 0.6 mm, which increased to 1.17 mm at 2 years follow-up visit. Clearly, there are more factors than just abutment gingival height to influence crestal bone stability.

Although soft tissue thickening with submerged 2 mm healing abutment did not preclude bone loss, the vertical soft tissue thickness increased significantly, when compared to the initial situation. It is interesting to note that the thickness was recorded to be 3.65 mm, while very similar to the outcome with other thickening techniques, like soft tissue grafting with membranes. For example, the study showed 3.8 mm in two stages with allogenic matrix, 3.65 with xenogeneic soft tissue substitute. In the light of a histological study by Tomasi et al, which reported 3.60 mm of full vertical soft tissue thickness, we can assume that **optimal tissue thickness is in a range between 3 and 4 mm. Recent data from another clinical trial confirm that minimal soft tissue thickness should be 3 mm, not 2 mm, as it was suggested by Lindhe and Berglundh.** The first animal study, which actually suggested that soft tissue thickness is important, in the control group had 3.65 mm of tissue thickness, in a group, which did not have any bone loss. It should be noted, that three implants in the epicrestal group experienced premature exposure before the second stage surgery. Interestingly, those were implants with the highest crestal bone loss reaching up to 1.28 mm after delivery and 1.32 mm after 2 years follow-up. It is possible that 2 mm healing abutments create the pressure on the tissue thinner than 2 mm (medium thickness 1.85 mm, Table 4), what leads to their perforation and subsequent bone loss. In conclusion, it must be admitted that the use of the tenting technique to increase vertical soft tissue thickness should be performed cautiously, if initial tissue thickness is less than 2 mm and probably other augmentation techniques should be pursued.

One disadvantage of the study was that soft tissue increase was not measured in the subcrestal group. The reason was that identical measurement like in epicrestal group was not possible, because at the time of the second stage surgery and higher 4 mm healing cap connection, subcrestal implants did not have developed full soft tissue seal, as the implant was submerged during the first stage surgery. Also, additional surgery just for measurement of the soft tissues was considered unethical from patient stands.

Statistical analysis was performed at the implant level, because eight patients received multiple implants, and that could be considered as another limitation of the study. The usual approach in those

cases to randomly select one implant/one patient approach was not pursued, as that would greatly reduce sample size and weaken the power of results. Statistical correction for multiple implants in the same patient was avoided due to high heterogeneity. In the authors' point of view, this approach deemed appropriate, as recent clinical publications in the field have similar amounts of implants and patients. Finally, one could argue that including only the posterior molar region into the study precludes the reflection of all populations, however, from the other hand, posterior mandible is the common place for thin biotype tissues. In addition, this study should be looked as the proof of concept, and accept the possibility, that in other regions of mouth some different results might be expected.

5 | CONCLUSIONS

Within the limitation of the study, it can be concluded that if thin soft tissues are diagnosed, subcrestal placement of rough surface bone level implants with platform switching and 7.5° conical connection can reduce crestal bone loss up to neglectable 0.18 mm after 2 years.

Soft tissue tenting of epicrestal implants with 2 mm healing abutments can increase tissue thickness to 3.65 mm, however, leading to greater bone loss of 0.51 mm.

AUTHOR CONTRIBUTIONS

T.L. conceived the idea. A.P. placed the implants. J.A. restored the implants. R.L. and G.E. collected the data. L.L. analyzed the data. T.L. led the writing.

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