The Influence of Initial Soft Tissue Thickness on Peri-Implant Bone Remodeling

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ABSTRACT

Aim: To elucidate the influence of initial soft tissue thickness on peri-implant bone remodeling. The research hypothesis was that implants installed in patients or at sites with thin mucosal tissues would show increased peri-implant bone loss.

Material and Methods: 79 edentulous patients were consecutively treated with two non-splinted implants supporting an overdenture in the mandible. During recall-visits, peri-implant health was determined by means of probing pocket depth and the modified plaque/bleeding index. Digital peri-apical radiographs were taken from individual implants. Bone level changes were measured from a reference point (lower border of the smooth implant collar) to the marginal bone-to-implant contact level. The linear mixed-effect model analysis was adopted to analyze the influence of clinical parameters and transmucosal abutment height on peri-implant bone loss.

Results: 67 patients attended the 1-year and 66 the 2-year recall-visit. Mean bone level changes were 0.89 mm (SD 0.62) and 0.90 mm (SD 0.66), plaque scores 0.82 (SD 0.94) and 0.87 (SD 0.92), bleeding scores 0.46 (SD 0.68) and 0.56 (SD 0.72) and PPD 1.65 mm (SD 0.60) and 1.78 mm (SD 0.59) after 1 year and 2 years respectively. The linear mixed-effect model revealed increasing bone level changes with decreasing abutment heights. Peri-implant bone level changes were significantly higher for implants with abutments of <2 mm (1.17 mm, $p < .01$; 1.23 mm, $p < .01$), 2 mm (0.86 mm, $p < .01$; 1.03 mm, $p < .01$) or 3 mm (0.38 mm, $p = .046$; 0.41 mm, $p = .044$) compared to ≥4 mm-abutments (bone level changes set to zero as reference value) both after 1 year and 2 years and bone level changes were significantly influenced by probing pocket depth ($p < .01$, $p < .01$), but not by plaque ($p = .31$, $p = .09$) and bleeding scores ($p = .30$, $p = .40$).

Conclusion: The present study suggests that implants with lower abutments, reflecting the initial gingival thickness, lose more peri-implant bone, possibly by a re-establishment of the biological width.

KEY WORDS: biologic width, dental implant, overdenture, peri-implant bone loss, soft tissue

INTRODUCTION

The dentogingival junction defines the soft tissue dimensions around teeth including the gingival sulcus, the junctional epithelium and supracrestal connective tissue. Gargiulo and colleagues found an average biological width, referring to the epithelial and connective tissue attachment of 2.04 mm around natural teeth in human skulls with corresponding average measures of 0.69 mm for the sulcus depth, 0.97 mm for the junctional epithelium and 1.07 for the connective tissue attachment. They further described a stable dimension in relation to the alveolar crest, but an individual variation was observed within patients and within sites of the same patient, especially in the epithelial component.[1] These findings were confirmed by Vacek and colleagues with the description of an average biological width of 1.91 mm in human cadaver jaws.[2] The term periodontal biotype was described by Seibert and Lindhe.[3] They described a thick-flat biotype with quadratic-looking teeth and a wide and voluminous zone of keratinized tissue and a thin-scalloped biotype with slender teeth and very narrow zones of keratinized tissue. De Rouck and colleagues found 1/3 of their sample corresponding to previously described thin-scalloped biotype and 2/3

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to a clear thick biotype. However, only half of the subjects in the latter group corresponded to the classical thick-flat biotype. The other half showed a clear thick biotype but with slender teeth and narrow zones of keratinized tissue and a high gingival scallop.[4] From periodontal research, the importance of the biotype is recognized especially in relation to the esthetic appearance. Subjects with a thin-scalloped biotype are more prone to gingival recessions, whereas thick-flat biotypes seem more resistant to trauma and hence protected against gingival recessions.[5]

The outcome of dental implants is overall related to implant survival and bone preservation. These factors are included in success criteria and often used to scrutinize implant systems, surgical, or prosthetic treatment protocols. Aside from the implant being an important factor for peri-implant bone healing, multiple other factors, such as smoking habits, occlusal overload, and surgical trauma, are playing a role in peri-implant bone preservation and, consequently, implant success.[6,7] Over the last two decades, the understanding of biology has improved and osseointegration of dental implants has become more predictable. Simultaneous to this evolution, more attention was paid to the esthetic outcome in terms of soft tissue preservation. The crestal bone supports the gingival architecture. Therefore, the stability of the crestal bone is believed to be the key factor for maintaining stable soft tissue dimensions over time. Likewise natural teeth, the same soft tissue barrier consisting of an epithelial part and a connective tissue part is found around dental implants. However, important quantitative and qualitative differences exist. An average biological width of 3.08 mm was described around non-submerged implants installed in a one-stage surgical procedure[8] and 3.42–3.80 mm around submerged implants installed in a two-stage surgical procedure.[9,10] Besides the dimensional differences with teeth, a different collagen fiber orientation was observed in the peri-implant connective tissue component. Collagen fibers were primarily parallel to the implant surface, whereas the inserting fibers were predominantly perpendicular in natural teeth.[11] This biological dimension and composition of the tissue is hardly influenced by the implant system.[9] Hermann and co-workers showed that the presence of a microgap, especially in close contact to the alveolar crest, significantly influences peri-implant bone loss and loss of soft tissue dimensions. In the absence of a microgap (in one-piece implants), the soft tissue dimensions are more similar to natural teeth compared to two-piece implants.[12] Linkevicius and colleagues showed significantly more peri-implant bone loss when tissues were thinner than 2 mm irrespective of the position of the micro-gap. On the contrary, implants at sites with thick mucosal tissues showed statistically significantly less crestal bone loss. The latter study suggests that the influence of the initial thickness at the time of implant installation might be more important on early bone remodeling than the position of the microgap.[13] A recent pilot study by the same author showed that platform-switching does not preserve the crestal bone better compared with a traditional flat-to-flat connection when thin mucosal tissues are present at the time of implant placement.[14] Collaert and De Bruyn (2002) suggested a relation between the height of the transmucosal abutment and peri-implant bone loss, although this was not statistically analyzed.[15]

To our knowledge, the impact of the soft tissue thickness on bone remodeling has received little attention and may be a clinical factor that is largely overlooked during clinical research. Hence, the aim of the present study focused to elucidate this aspect in detail.

The research hypothesis was that implants installed in patients or at sites with thin mucosal tissues would show increased peri-implant bone loss because of the biological necessity to create enough space for re-establishment of a protective soft tissue seal acting as a barrier against bacterial contamination.

MATERIALS AND METHODS

Patient Population and Surgical/Prosthetic Procedures

Seventy-nine completely edentulous patients were consecutively treated with two non-splinted implants supporting an overdenture in the mandible. Both surgery and prosthetics were performed by the same clinician (JB). Dental implants (Astra Tech™, Mölndal, Sweden) measuring 4 mm in width and ranging between 8 and 17 mm in length were installed according to the manufacturer's guidelines. In most cases, the existing removable denture was converted to a guide plate by drilling two access holes at the planned surgical sites, being incisor or canine location. A full-thickness mucoperiosteal flap was prepared to expose the interforaminal bone, and implant recipient sites were prepared using the removable denture as direction guide plate. Care was

taken to have the implant completely surrounded by bone after implant placement. In case of a knife edge or in case a dehiscence could be expected because of a tiny crest, the bone was reduced in height prior to implant installation. The height of the transmucosal healing abutment was chosen by the surgeon in function of the soft tissue thickness. The abutment was more or less flush with the soft tissue level after suturing and, when necessary, another healing abutment was placed after suturing. The aim was to avoid the healing abutment to be interfering with the denture base and to avoid weakening of the prosthesis by too-extensive grinding. The abutment was not allowed to stick out more than 1 mm because uncontrolled premature contacts with the denture base could possibly result in higher failure risks. As a consequence of this standardized approach, the height of the healing abutment reflected the initial soft tissue thickness. The clinical procedure has previously been described in detail and is basically a one-stage early-loading procedure.[16] The denture was relined with a soft relining material (Ufi-gel, Voco, Cuxhaven, Germany), either immediately or at the time of suture removal 7 days after surgery. Antibiotics were given routinely starting 1 hour before surgery (clindamycin 300 mg thrice daily for 5 days). A plaque control regimen was instructed from day 0 by means of 0.05% chlorhexidine rinsing (Perio-aid, Dentaid, Houten, the Netherlands) and patients were advised to brush the healing abutments with a very soft toothbrush (Surgical Care, TePe, Malmö, Sweden). The patients were regularly checked until the healing abutments were changed by ball or locator abutments after soft tissue healing (Figure 1, A and B). This was prior to the final impression for the new overdenture and varied from patient to patient from 2 weeks to 3 months after surgery. The retentive element of the abutments was located to the nearest distance to the soft tissue (Figure 1, A and B) and the acrylic denture was in close contact with the soft tissue in order to prevent soft tissue overgrowth and minimize the lever effect (Figure 1, C and D). The final prosthesis was metal- or glassfiber-reinforced at the lingual side (Figure 1E) and was installed within 4 months after implant installation. The treatment always included a new complete denture in the maxilla to idealize function and esthetics using the lingualized occlusion concept (Figure 1F). After finalizing the prosthetic treatment, the patients were given oral hygiene instruction and scheduled for professional maintenance by an oral hygienist at least once a year. The recall interval was individually determined, depending on the patient's ability to perform oral hygiene measures.

Clinical and Radiographic Examination

Once a year, all patients were invited to attend a recall visit organized by an independent research team from the University of Ghent. In brief during this visit, peri-implant health was determined by means of the peri-implant probing depth and the modified plaque and bleeding index.[17] The clinical examination parameters were assessed on four implant sites (midmesial, middistal, midbuccal, and midlingual) and averaged to obtain a single value per implant. Digital peri-apical radiographs were taken from each individual implant using a guiding system (Rinn XCP®, Dentsply, York, PA, USA) in order to obtain the X-ray direction perpendicular to the film. Whenever the implant threads were unclear, new radiographs were taken until the radiologic bone-to-implant contact level could be determined. The computer calliper available in the data program (Visiquick, Amsterdam, the Netherlands) was used for the assessment of the marginal bone level under appropriate magnification. We used magnifications in the computer software program up to 200% whenever necessary to evaluate the bone level. Possible distortions were adjusted by calibrating the measurements with the known implant width and abutment height. The lower edge of the smooth bevel of the coronal part of the implant was the baseline reference point as shown in Figure 2. Bone level changes were measured from this reference point to the most marginal bone-to-implant contact point. Mesial and distal values were averaged to obtain one single value per implant. This was statistically sustained because paired analysis did not show a statistically significant difference between mesial and distal values ($p > .05$). The research analysis of the current study are using the data of all consecutively treated patients from the start of the project in 2005 until the last research visit (January 2011).

Statistical analysis was performed using *SPSS*® 19 for Windows (SPSS Inc., Chicago, IL, USA). The linear mixed-effect model analysis was adopted to analyze the influence of bleeding on probing, plaque, and abutment height on peri-implant bone loss in order to correct for clustering implants in the same patient. Data were analyzed first in terms of linearity and homoskedasticity as requirements for mixed-model analysis. The study protocol was approved by the ethics committee of the

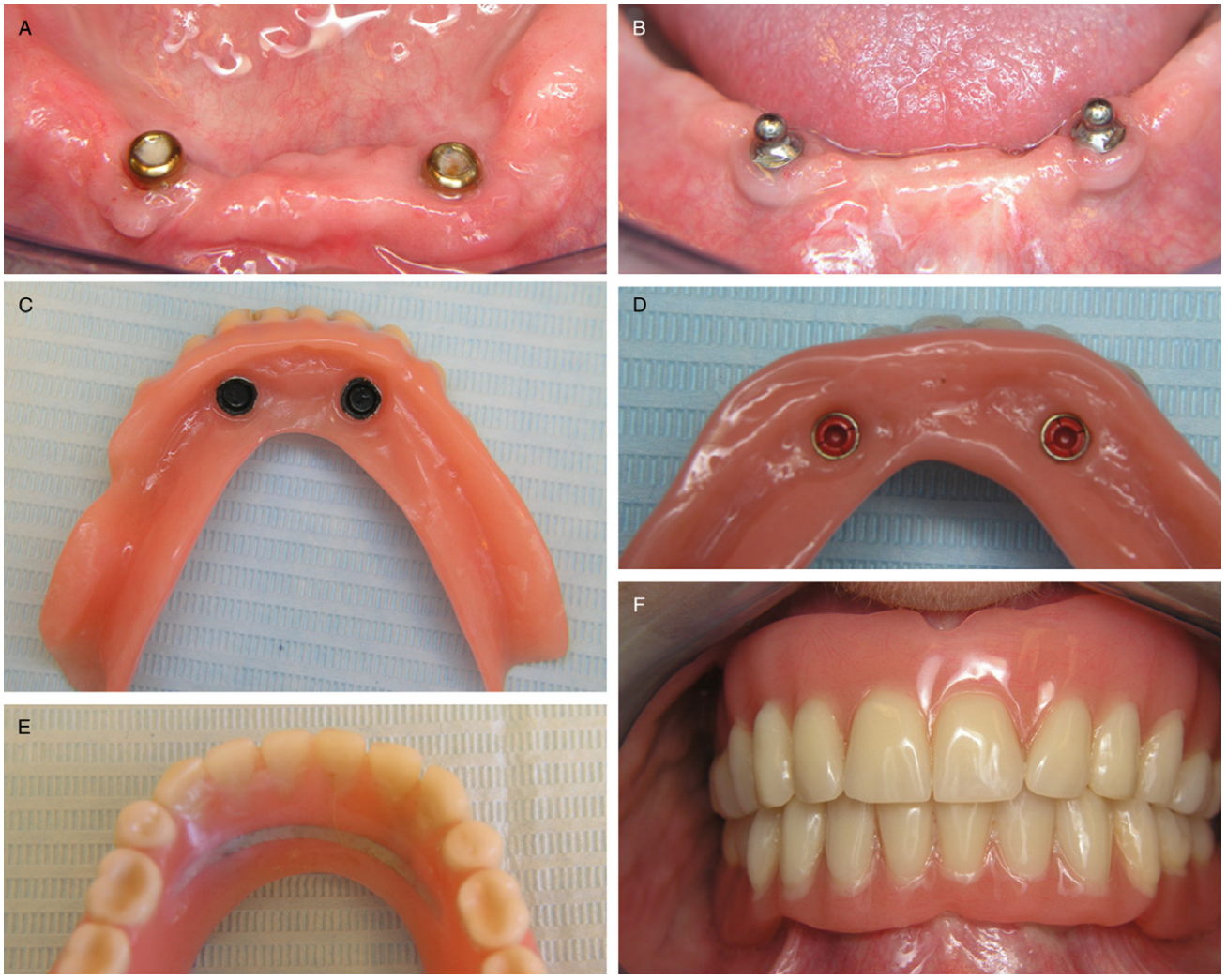

Figure 1 Clinical images showing 2 transmucosal locator abutments (A) or ball abutments (B) to support a mandibular overdenture with the respective retention connectors (C,D). Treatment always included a metal- or glass fiber-reinforced mandibular overdure (E) and a new complete denture in the maxilla (F) to idealize function and esthetics.

University Hospital of Ghent University and all patients were examined only after written consent was obtained.

RESULTS

Seventy-nine patients were consecutively treated with 158 implants to support a mandibular overdenture. 67 patients were attending the 1 year recall and 66 the 2-year recall. The mean bone level changes after 1 year and 2 years of follow-up were 0.89 ($n = 134$, SD 0.62, range 0–3.35) mm and 0.90 mm ($n = 132$, SD 0.66, range 0–3.15) respectively. 61.9% and 60.6% of the implants showed ≤1 mm of bone level changes after 1 year and 2 years respectively (Figure 3A). Mean bleeding scores, plaque scores and probing pocket depth after 1 year and 2 years are given in Table 1.

A linear mixed-effect model analysis was performed to scrutinize the influence of abutment height, bleeding scores, plaque scores and probing pocket depth on bone level changes after 1 year and 2 years of follow-up. This statistical analysis corrects for clustering implants in the same patient. Results are given in Table 2. The abutment height and probing pocket depth were found to be statistically significant factors both after 1 year and 2 years of follow-up. Bleeding scores and plaque scores did not influence peri-implant bone level changes.

In depth analysis is given in Table 3. Peri-implant bone loss was significantly higher for implants with an abutment of <2 mm, 2 mm or 3 mm compared to implants with an abutment of ≥4 mm. Signifcant additional bone level changes are observed for implants with an abutment of <2 mm (1.17 mm, $p < .001$; 1.23 mm,

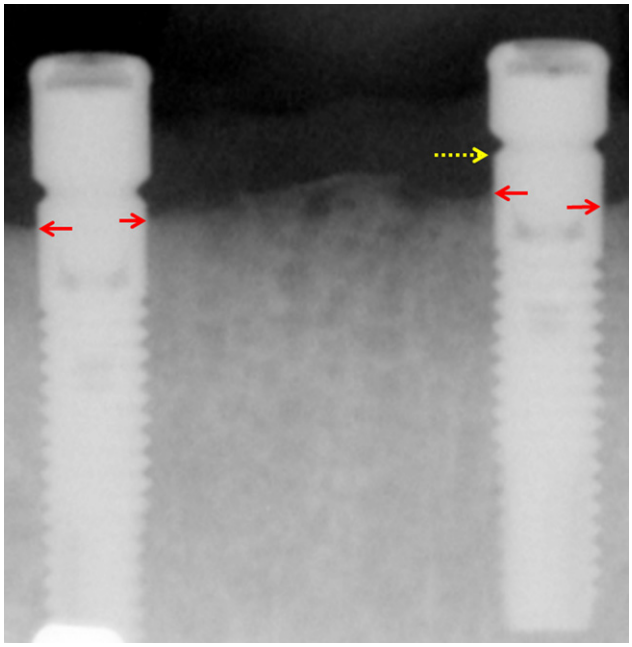

Figure 2 Bone level changes were assessed from the reference point, being the lower border of the smooth implant collar (yellow dotted arrow) to the most marginal bone-to implant contact level (red arrow. The radiograph shows more bone loss on the short locator abutment (right) compared to to long locator abutment (left).

TABLE 1 Mean (SD) Bone Level Changes after 1 and 2 Years and Respective Plaque/Bleeding Scores and Probing Pocket Depth

	1 Year			2 Years		
	Mean	Range	SD	Mean	Range	SD
Bone level changes (mm)	0.89	0–3.35	0.62	0.90	0–3.15	0.66
Plaque scores	0.82	0–3	0.94	0.87	0–3	0.92
Bleeding scores	0.46	0–3	0.68	0.56	0–3	0.72
Probing pocket depth	1.65	1–4.25	0.60	1.78	1–3.35	0.59

$p < .001$), 2 mm (0.86 mm, $p < .001$; 1.03 mm, $p < .001$) or 3 mm (0.38 mm, $p = .046$; 0.41 mm, $p = .044$) compared to implants with ≥4 mm abutments (parameter set to zero as a reference value) after 1 year and 2 years respectively. Implants with deeper pockets, show more peri-implant bone loss. When the pocket depth increased with 1 mm, bone level changes increased with 0.34 mm after 1 year or 0.28 mm after 2 years. This is illustrated in figure 3B showing the cumulative percentage of bone level changes in relation to the abutment

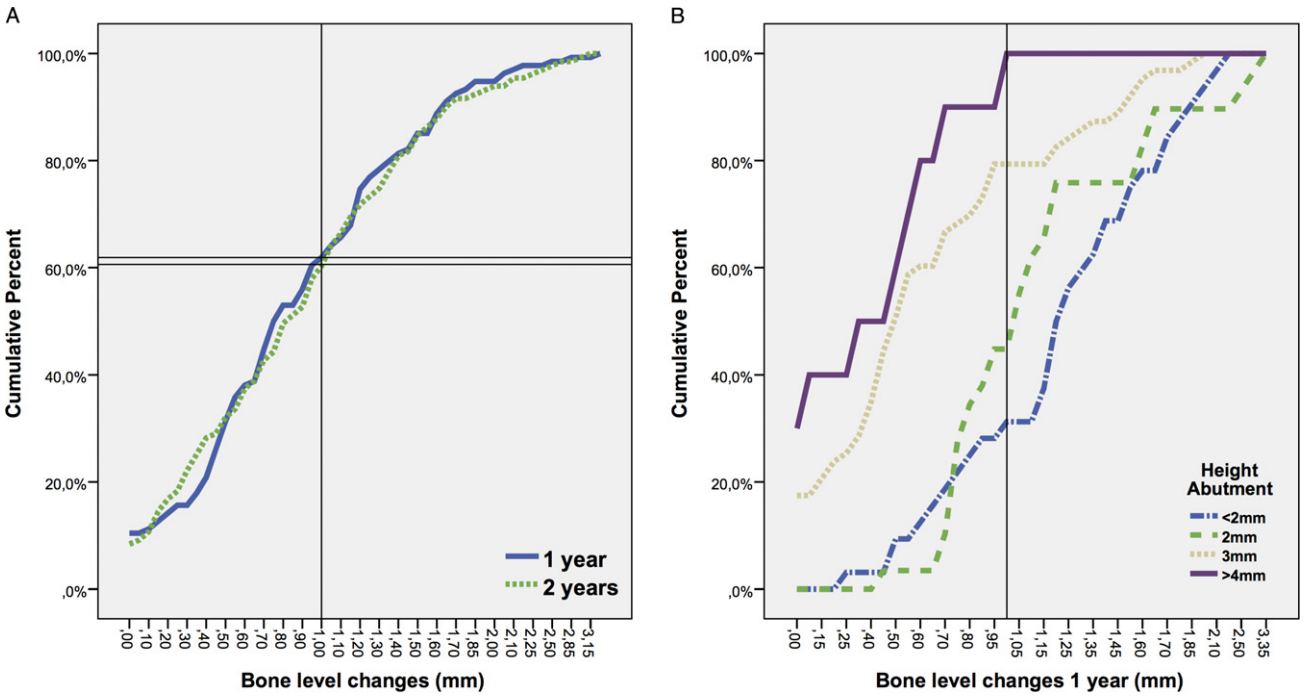

Figure 3 *A* Showing cumulative peri-implant bone level changes for all individual implants ($n = 134$ after 1 year and $n = 132$ after 2 years of follow-up). When taking 1 mm as a threshold, 61.9% and 60.6% of all implants were considered a success after 1 year and 2 years respectively. *B* Showing cumulative peri-implant bone level changes for all individual implants after 1 year in relation to the abutment height. When taking 1 mm bone level change as a threshold, all implants with a ≥4 mm abutment were considered a success. The corresponding values for abutments of 3 mm, 2 mm or <2 mm were 79.4%, 44.8% and 31.3%.

TABLE 2 Results of Mixed-Effect Model Analysis on the Influence of Abutment Height, Plaque/Bleeding Scores and Probing Pocket Depth on Bone Level Changes after 1 Year and 2 Years of Follow-Up

Main Effects	1 Year	2 Years
Abutment height	<0.01*	<0.01*
Plaque scores	0.31	0.09
Bleeding scores	0.30	0.40
Probing pocket depth	<0.01*	<0.01*

*Statistically significant at the 0.05 level.

height and suggests that implants with smaller abutments, reflecting less initial gingival thickness, lose more peri-implant bone, possibly by a re-establishment of the biological width (Figure 4). When taking 1 mm bone level change as a threshold for success, all implants with an abutment of ≥4 mm were successfull. The corresponding values for implants with abutments of 3 mm, 2 mm and <2 mm were 79.4%, 44.8% and 31.3%.

DISCUSSION

The present study reports mean bone level changes around early loaded non-splinted implants installed to provide retention to a mandibular overdenture of 0.89 mm and 0.90 mm after 1 year and 2 years respectively. This outcome is in accordance with other clinical reports evaluating the same implant system and reporting peri-implant bone loss ranging from 0.24 mm to 1.3 mm[18–22] with overall steady-state bone levels after initial bone remodeling. In the present study, bone levels were measured from a reference point, the lower border of the smooth implant collar, up to the most marginal bone-to-implant contact level. This reference point is generally accepted and was described by previous authors using the same implant system.[18–20,22,23] As mean values may hide important information, it is important to present additional information such as the range of values. Bone level changes ranged from 0 mm to 3.35 mm after 1 year and from 0 mm tot 3.15 mm after 2 years of follow-up. No increase was found in the range from 1 year to two years of follow-up as reflected by the cumulative percent of bone level changes after 1 year (61.9% ≤ 1 mm) and 2 years (60.6% ≤ 1 mm) (Figure 3A).

Early bone remodeling was not influenced by plaque and bleeding scores in the present study. These results are in contradiction with previous papers.[24–26] In the present study patients were well-maintained and had relatively low plaque and bleeding scores. Whenever

TABLE 3 Linear Mixed-Effect Model Analysis Showing the Effect of Abutment Height, Plaque/Bleeding Scores and Probing Pocket Depth on Peri-Implant Bone Level Changes

		1 Year				2 Years			
		Estimate	SE	*p*-Value	95% CI	Estimate	SE	*p*-Value	95% CI
Intercept		−0.29	0.37	0.46	−1.05–0.48	−0.16	0.42	0.70	−1.00–0.68
Abutment height	<2 mm	1.17	0.20	<0.01*	0.76–1.57	1.23	0.22	<0.01*	0.80–1.66
	2 mm	0.86	0.20	<0.01*	0.46–1.26	1.03	0.23	<0.01*	0.57–1.49
	3 mm	0.38	0.19	0.046*	0.01–0.74	0.41	0.20	0.044*	0.01–0.81
	≥4 mm	0†				0†			
Plaque score	0	−0.19	0.23	0.40	−0.65–0.26	−0.22	0.20	0.30	−0.63–0.19
	1	−0.33	0.23	0.15	−0.79–0.12	−0.24	0.19	0.21	−0.62–0.14
	2	−0.34	0.22	0.14	−0.78–0.11	0.10	0.20	0.63	−0.30–0.50
	3	0†				0†			
Bleeding score	0	0.17	0.34	0.62	−0.50–0.84	−0.04	0.30	0.88	−0.63–0.55
	1	0.33	0.34	0.33	−0.34–1.00	−0.11	0.30	0.73	−0.70–0.49
	2	0.22	0.32	0.48	−0.40–0.86	0.17	0.32	0.60	−0.46–0.80
	3	0†				0†			
Probing pocket depth		0.34	0.09	<0.01*	0.16–0.51	0.28	0.09	<0.01*	0.10–0.46

*Statistically significant difference at the 0.05 level. This table shows that an implant with an abutment of <2 mm lost on average 1.17 mm and 1.23 mm more peri-implant bone after 1 and 2 years respectively, compared to an implant with an abutment of 4 mm or more.
†Parameter set to zero as a reference value.

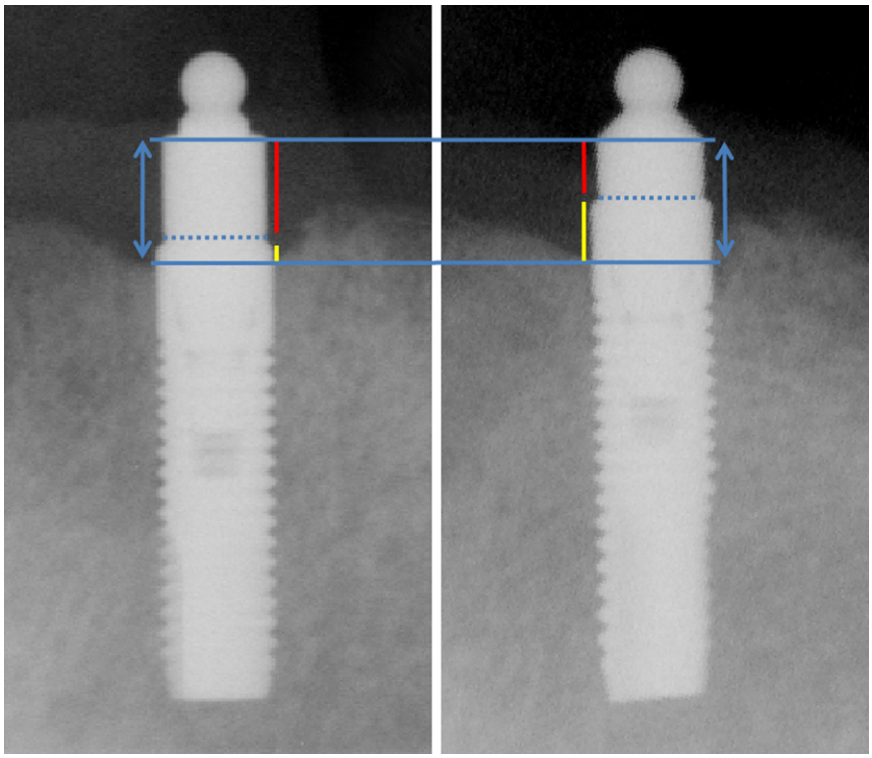

Figure 4 Illustration of the biological width on peri-apical radiographs of an implant with a ball abutment of 3.0 mm (left) and 1.5 mm (right)in the same patient. The blue arrows are indicating the sum of the abutment height (red line) and bone level changes (yellow line). The implant with the abutment of 1.5 mm lost more peri-implant bone compared to the other implant (yellow lines) with the abutment of 3.0 mm.

necessary, the individual maintenance program was reinforced. This may explain why results were not influenced by plaque and bleeding scores. Moreover, Verhoeven and co-workers analyzed the reliability of different periodontal parameters to reflect the clinical condition of a dental implant. They found a rather poor specificity and sensitivity for the plaque and bleeding index and considered the aforementioned parameters as unreliable for clinical evaluation in implant dentistry.[27] They suggest that radiographs are needed to assess critical peri-implant bone level changes. Likewise, it was shown that the absence of bleeding on probing is a parameter with a high negative predictive value (98.5%) indicating periodontal stability around natural teeth, rather than the presence of bleeding on probing as a positive indicator for disease.[28,29]

The present study shows that early bone remodeling is influenced by the initial soft tissue thickness at the time of implant placement as reflected by the height of the abutment. Greater bone level changes were observed in cases where small abutments were placed. We did not measure the thickness of the sot tissue at the time of implant placement because originally this was not the aim of our study. But after 1 year we noticed more crestal bone loss around implants with short abutments. However, due to the standardized protocol decribed in the materials and methods, the heigt of the abutment reflects the initial sof tissue thickness. This relationship was already described by Collaert & De Bruyn (2002), but not statistically analyzed. They treated a group of 25 edentulous patients with 4 to 5 mandibular implants each. Conical abutments were used as transmucosal components and restored with a fixed screw-retained cross arch restoration. They observed that short abutments, installed when thin mucosal tissue thickness was present, resulted in an increased peri-implant bone remodeling. They attributed this bone loss to biological width establishment requiring enough space for the biological dimensions.[15] When applying the same immediate loading protocol using implants with a grit-blasted surface (TiOblast™, Astra Tech™, Mölndal, Sweden) in both maxilla or mandible, they found more initial peri-implant bone remodeling in the mandible compared to the maxilla. The authors attributed this to different surgical flap preparation and slightly subcrestal implant placement in the maxilla aiming both for soft tissue

thickness in the maxilla and more space for biological width formation. In the mandible implants were often placed flush with the crest which in combination with thin tissues may provide too little space for the biological attachment.[18,19] The results in the present study are also in accordance with the results of a randomized clinical trial reporting that up to 1.45 mm of bone loss can occur after 1 year in cases with thin mucosal tissues at the time of implant placement.[13] In the present study a mean bone loss of 0.89 mm is described after 1 year. This is slightly better compared with the aforementioned study. A possible explanation is that implants with a different connection were used in both. In the present study implants with an internal conical connection were installed. It is well-known that an internal connical connection minimizes microbiol leakage[30] and micro-movements[31] preventing crestal bone loss. An other study by the same authors reported a mean bone loss at sites with thin mucosal tissues of 1.81 mm on the mesial and 1.70 mm on the distal aspect for implants with platform-switching and 1.60 mm on the mesial and 1.76 mm on the distal aspect of implants without platform-switching.[14] They concluded that soft tissues of ≤2 mm are insufficient for a stable peri-implant seal formation. This factor may be more important than the type of implant-abutment connection. In literature a biological width of 3.08 mm was described around non-submerged implants.[8] After implant placement, it is believed this biological width establishes. In case of soft tissues of 2 mm, this precludes either 1 mm of bone loss or a soft tissue regrowth through hypertrophia. Since the base of the relined removable denture was made in direct contact with the gingiva, very limited gingival hypertrophia could occur. Nevertheless, the same phenomenon was observed in immediately loaded full-arch, mandibulary rehabilitations on 5 implants. Despite enough space, provided for oral hygiene measures, still peri-implant bone loss was observed.[16] On the other hand, in a recent paper by the same authors, very limited bone loss was observed for the same treatment, but with a deeper implant placement protocol in cases of limited bone volume in order to avoid buccal dehiscences.[32] In other indications, such as single-tooth replacement, a regrowth of the papilla is often observed after delivery of the final restoration.[33] However, the level of the alveolar crest at the neighbouring teeth[34–38] and a proper crown design[39] allow the gingiva to fill the interproximal embrasures. This is not possible in overdenture cases. This might explain the greater bone level changes around implants with short abutments in the present study.

CONCLUSION

The results of the present study suggest an anticipation on the bone-remodeling that occurs after implant placement in healed sites by adapting the vertical position of the implant to the thickness of the gingiva. Especially patients or sites with inadequate gingival thickness may present more peri-implant bone loss after re-establishment of the biological width when implants are placed equally with the crest as described in the manufacturer's guidelines. Although deeper placement is suggested to induce crestal bone loss due to the microgap between implant and abutment during the initial healing stage, this may be preferable to unforseen exposure of the implant neck. The latter may lead to soft tissue recession and could hamper aesthetics as well as increase the risk for soft and hard tissue pathology due to exposure of the implant threads. Hence, it is suggested that the surgeon should proactively keep soft tissue thickness into account when installing implants especially in cases with a thin biotype. For future research it is suggested to include information on the soft tissue thickness, especially when implant systems or treatment protocols are evaluated or compared. Whether the findings in the present study are valid for all implant systems/implant connections remains to be investigated.

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