Retrospective analysis of augmentation procedures with umbrella screws, a novel tenting technique: a consecutive case series in 279 patients

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Objectives: The consecutive case series accesses the results and experiences of ridge augmentation using an umbrella screw tenting technique. **Method and materials:** In total, 279 patients were treated between 26 May 2015 and 16 June 2021, including horizontal and vertical ridge defects. Sex, age, smoking behavior, jaw, graft material, soft tissue thickness, extent of horizontal/vertical augmentation, resorption rate, and occurrence of early/late exposure were evaluated. Bone gain was determined by resorption at the screw head. Only cases without premature screw removal were evaluated metrically (n = 201). All other augmentations were evaluated according to whether implantation was possible with or without further augmentation (n = 27). A target performance index was calculated, which should enable evidence-based comparability of different augmentation methods in future. **Results:** In total, 54 wound dehiscences (39 early, 15 late exposures) occurred, which corresponds to 24.08% of the augmented sites; 42 umbrella screws were removed prematurely. In all cases an implantation was possible at the desired position afterwards. Cases with a vertical augmentation component showed a higher prevalence of exposure (early, $P = .000$; late, $P = .024$). The extent of the vertical augmentation was only relevant for early exposure ($P = .048$). Mean bone gain of 4.23 ± 1.69 mm horizontally and 4.11 ± 1.99 mm vertically could be achieved. Regression analysis showed that there was no limit in horizontal/vertical direction. Mean percentage target performance index was 75.90 ± 20.54 for vertical and 82.25 ± 16.67 for horizontal portions. **Conclusion:** The umbrella technique is an effective augmentation method, which can be applied to any defect morphology. *(Quintessence Int 2024;55:28–40; doi: 10.3290/j.qi.b4479067)*

Key words: horizontal ridge augmentation, implantation, ridge augmentation, target performance index, tenting technique, umbrella screws, umbrella technique, vertical ridge augmentation

Various techniques for ridge augmentation have been introduced and scientifically examined in recent decades. The common aim is to gain enough bone for placing the implant in the correct three-dimensional position and to achieve good long-term results.[1] Evidence of the superiority of a specific technique is lacking, and high complication rates have been reported.[2,3] A review of the European Workshop on Periodontology reported exposure rates between 5% and 54% with horizontal augmentation, and between 0% and 77.8% with vertical augmentation.[4] Serious complications such as infection and partial or total loss of the augmented material occurred with an incidence of 7% to 13%.[4] The major biologic principles for any ridge augmentation procedure are to stabilize the coagulum, to provide immobility, and to allow blood vessels to grow through the graft material (GM) or the transplanted bone to initiate ossification. Massive bone blocks provide stability by themselves but hinder vascularization due to their dense structure. Sometimes they integrate but do not turn over in living bone and thus may provoke subsequent infections. Particulate GMs do not have these issues, but in a more complex defect morphology they cannot maintain the volume sufficiently. Therefore, bone shells,[5] titanium reinforced membranes,[6] or titanium meshes[7] have been suggested. Fre-

quently, a high exposure rate with subsequent problems is detected,[8] and in case of sintered individual titanium meshes a high level of planning effort and high costs are associated.

In order to achieve predictable results with a reduced planning effort and lower material costs, the umbrella technique was developed. A tenting technique was published in 1967 using microosteosynthesis screws to stabilize the particulate bone substitute.[9] The screw heads had a diameter of 2 mm and sharp edges. The exposure rates of comparable screws were high in the present authors' opinion. To minimize this complication and to achieve higher space-maintaining properties, screws with a wider head and rounded edges were developed (umbrella screws [USs]).

The aim of the present consecutive case series was to report the results of ridge augmentation using the umbrella technique in different defect morphologies, and to discuss the occurred complications and their influence on the bone gain.

Method and materials

The study was approved by the ethical committee of the Goethe University in Frankfurt, Germany, with the registration code "2022-741-Retrospektive Datenauswertung," and carried out according to the principles of the Helsinki declaration.

The study population was treated in the private practice of FR and MS between May 2015 and August 2021.

The inclusion criteria were that the patient had at least one site with a horizontal and/or vertical ridge defect and gave informed consent for using the umbrella technique. The recipient site was free from acute or chronic infections.

The exclusion criteria were medical and/or general contraindications for intraoral surgical procedures, pregnant and nursing patients, and patients who were not able to consent to the therapy.

In total, 279 sites were augmented in 279 patients. One patient died during the healing period. Fifty patients were excluded from statistical analysis: n = 11 implant placement/reentry alio loco (patient was referred only for ridge augmentation surgery); and n = 39 reentry pending (at the time of data evaluation, the healing phase had not yet been completed). For analysis, the remaining 228 cases were allocated to the groups US1 (all USs in situ at reentry) (n = 201), US2 (several USs had to be removed prematurely, n = 14), and US3 (all USs had to be removed prematurely, n = 13). Two analysis steps were performed (Fig. 1).

- Analysis step 1 (US1+US2+US3):
  - exposure rate (early and late-
  - risk for premature screw removal
- Analysis step 2 (US1)
  - resorption rate
  - bone gain (vertical and horizontal)
  - target performance index (TPI; percentage and absolute)
- Analysis step 2 (US2):
  - implantation possible with or without the need for secondary augmentation
- Analysis step 2 (US3):
  - implantation possible with or without the need for secondary augmentation.

USs are made of surgical steel to avoid osseointegration and have a diameter of 1.2 mm. At the moment, two companies provide USs, with small differences. They are available with a head diameter of 4, 5, or 6 mm and a length of 8, 10, 12, or 13 mm (Fig. 2).

Surgical protocol and measurements

All the implants were placed in the authors' (FR and MS) private practice with an identical protocol, by three surgeons. The surgery was performed by three of the authors (TS, FR, and MS). All the results were assessed by the individual surgeon who augmented during implant placement during the treatment steps. Data assessment followed (instructed by MS, and taught on one occasion before the first surgery). The treatment was performed under local anesthesia (Ultracain DS Forte, Sanofi-Aventis). The antibiotic regime was amoxicillin-clavulanic acid 875/125 mg twice a day (1-0-1) starting 2 hours prior to surgery for 1 week. Clindamycin 600 mg was administered three times daily (1-1-1) in the case of a penicillin allergy. After crestal incision with, when needed, releasing incisions located distally and/or mesially of the adjacent teeth, a full flap was raised. Beyond the mucogingival junction a split-thickness flap was prepared buccally, and in the mandible also on the lingual aspect to achieve tension-free wound closure. USs were placed as required, providing an additional 1 mm of space to ensure adequate volume after settling of the GM. The number and position of the USs was determined by the defect morphology and size. Screws were placed to provide an immobile space, a prerequisite of bone augmentation procedures. Decortication or cortical perforation was not performed. The defect was defined as horizontal, vertical, or combined. Soft tissue thickness and horizontal and/or vertical augmentation volume were measured with a periodontal probe with a 1-mm scale (PCPUNC 15, Hu-Friedy). The amount of augmentation was measured from the bottom of the screw head to the farthest bone margin (Fig. 3).

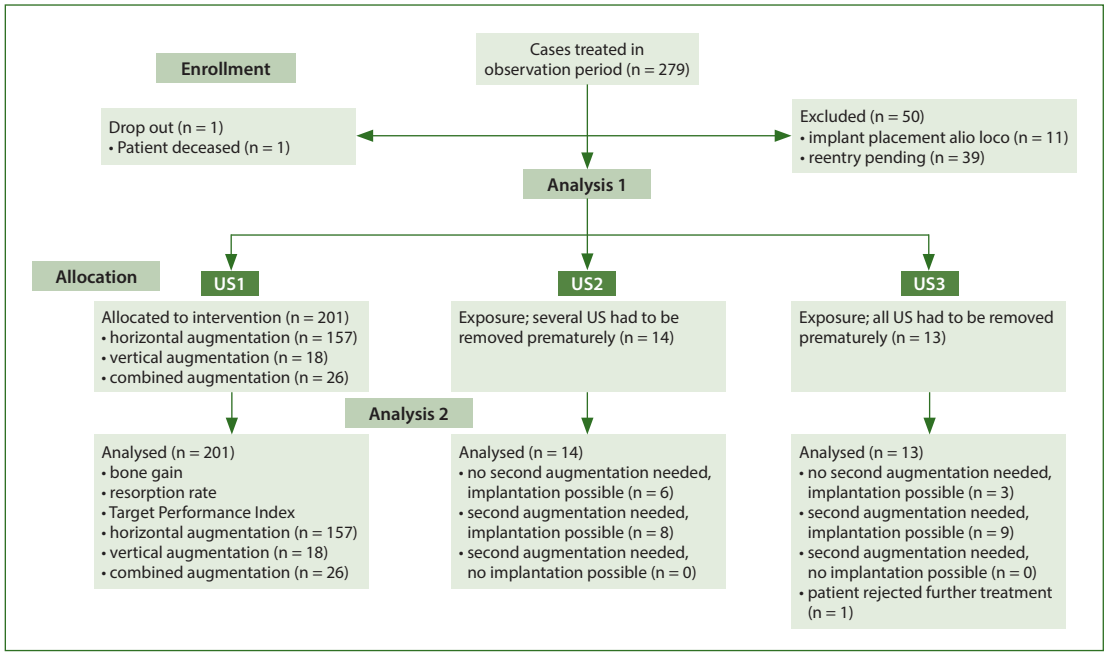
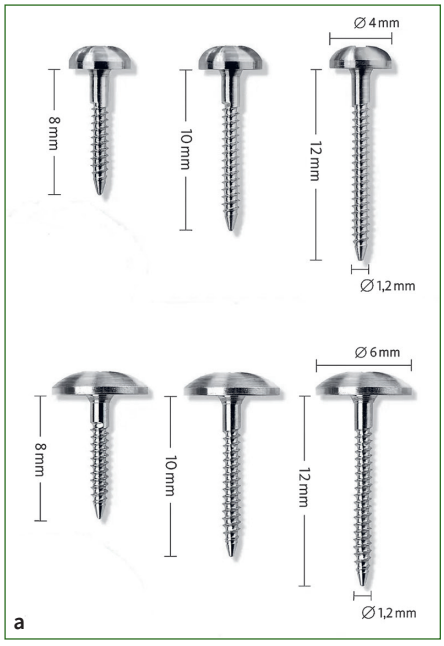


Fig. 1 Flowchart of the retrospective study of augmentation with umbrella tenting screws.



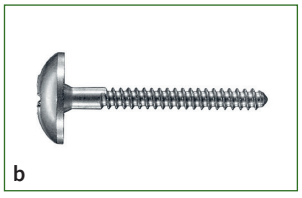


Fig. 2a and b Available USs with head diameter between 4 and 6 mm, length between 8 and 12 mm. US from Ustomed (reprinted by permission of Ustomed *(a)*. US Schirmschrauben, Geistlich (reprinted by permission of Geistlich) *(b)*.

The defect volume was filled with particulate GM. Since the data reflect routine treatment in a specialized practice, the choice of GM was adapted to the patients' preferences, after instruction by the surgeon. GM comprised either:

- autologous bone chips (AB) alone, harvested with a safe scraper (Geistlich Biomaterials) from the ramus area
- a mixture of AB with xenogeneic bone substitute (AB/XBS; Bio-Oss, Geistlich Biomaterials) in a mixture ratio of 1:1
- or allogeneic (ABS) Maxgraft (Human Spongiosa CHB, Botiss Biomaterials) alone.

The GM was mixed with advanced platelet-rich fibrin (A-PRF) membrane cut into pieces in combination with injectable platelet-rich fibrin (i-PRF)[10,11] and covered with native collagen membrane (Bio-Gide, Geistlich Biomaterials). The flap was coronally advanced and sutured tensionless with horizontal mat-

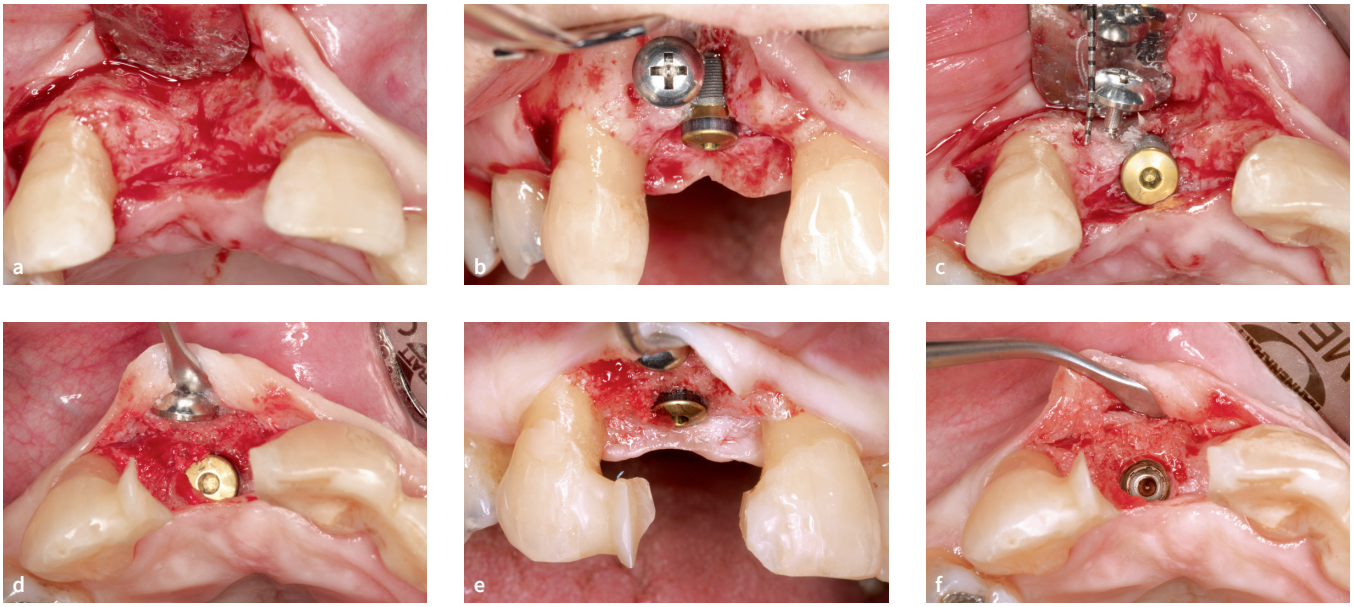


Fig. 3a to f US augmentation with simultaneous implantation. Horizontal alveolar ridge defect *(a)*. Implant (Astra EV D 4.2 mm L 9.0 mm; Dentsply Sirona) + tented-up volume (3 mm horizontal measured with a periodontal probe (PCPUNC 15; Hu-Friedy) with US (Ustomed) + 2 mm healing cap *(b and c)*. Clinical situation after 6 months without any resorption *(d to f)*.

tress suture and adapting suture on top by using 6/0 polypropylene monofilaments (Medic). The sutures were removed after 14 days. In 58 cases, simultaneous implantation could be performed. Sites healed for 6 months, when using AB or ABS, and 9 months, when using AB/XBS. In the case of exposure, the patients were instructed to brush the area carefully, rinse the site with chlorhexidine, and return for a weekly check-up until the situation was stable. Exposures evident in the first 14 days after surgery were allocated as early exposure. Subsequent exposures were allocated as late exposures. USs were removed if screw mobility or infection was observed. In these cases, the soft tissue defects were left for free granulation and closed by themselves within days. At stage-two surgery all remaining USs were exposed by full-thickness flap preparation. The distance between the bottom of the screw head to the farthest horizontal and/or vertical bone margin was measured with the periodontal probe. If more than one US was needed to augment the defect, the mean of the assessed distances was used for calculation to assess bone gain. All exposures, infections, and unexpected events were documented. Figure 4 shows a US augmentation case from the beginning to the end.

Efficacy of augmentation procedures comparing outcome and baseline are difficult to assess in clinical studies because of the lack of a reference point. The USs placed at the same level as the augmented surface provide such a reference point. At baseline the distance from the head of the US to bone level was assessed in the horizonal (US-hd) as well in the vertical dimension (US-vd). At reentry the distance from the head of the US to the newly formed bone (US-hnb and US-vnb) was assessed. The achieved horizontal bone gain (bg-h) was calculated as bg-h = US-hd – US-hnb. The vertical bone gain (bg-v) was calculated in a similar way. To evaluate efficacy, the target performance index (TPI) was calculated. The horizontal TPI was calculated as TPI-h = (bg-h)/(US-hd) × 100%. TPI-v was calculated in a similar way. The absolute index was calculated through the subtraction of bone gain and augmentation. In cases where the screw head is covered with bone at reentry, an index greater than 100% is possible.

Preoperative and postoperative radiographs or, if necessary, clinically preoperative CBCT were obtained at both augmentation and subsequent implant placement. In all nonsimultaneous cases, the early (before placement of prosthetic restoration) and late (until 09/2023) implant loss, the insertion torque, and the bone density as surrogate for the quality of the acquired new bone were assessed. Bone density of the newly formed bone was determined on drilling by the surgeon's tactile sense, and recorded as D1 to D4 based on Misch criteria.[12] The insertion torque of the implants placed in the augmented bone was assessed by the surgical motor (Implantmed, W&H).

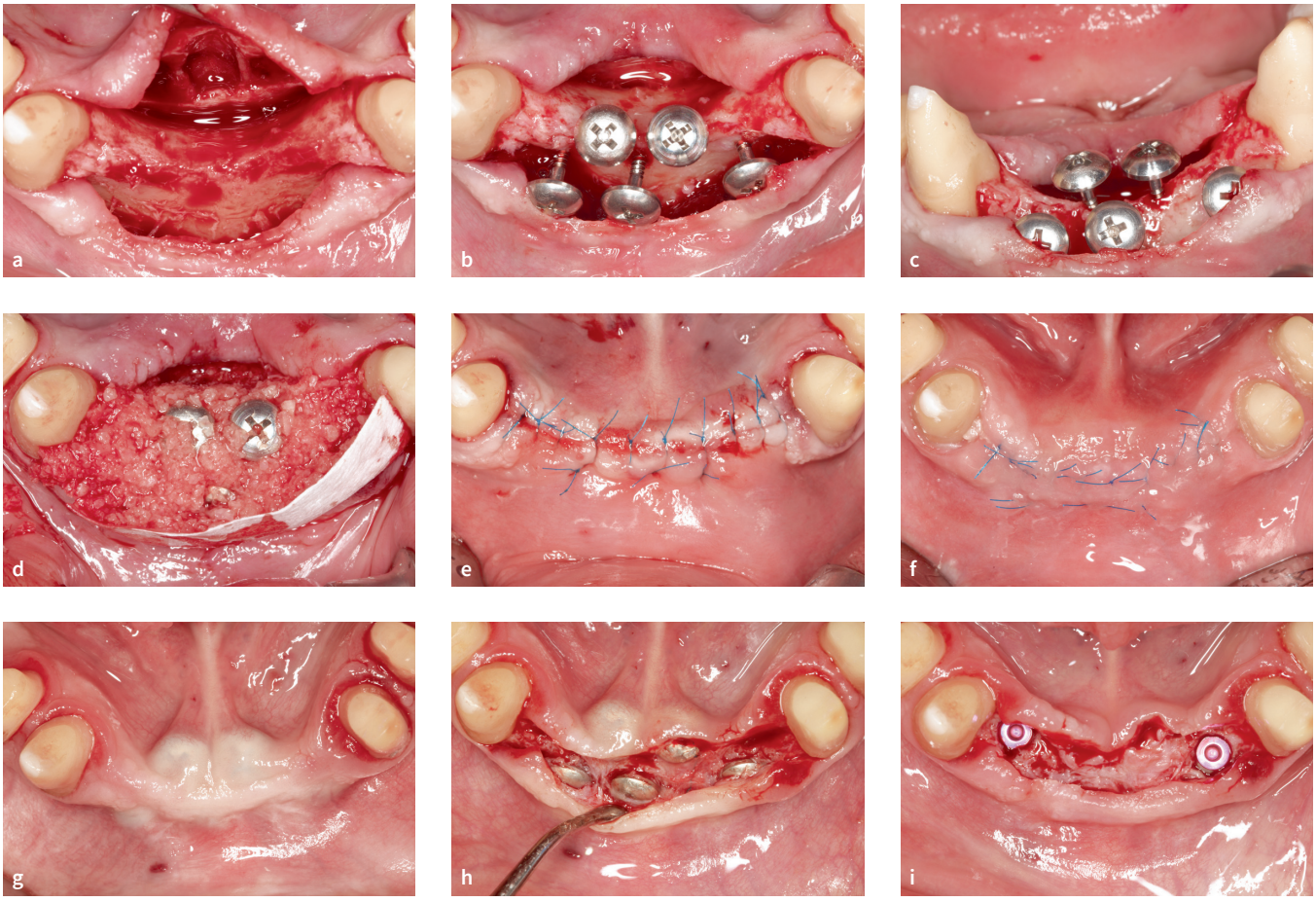


Fig. 4a to i US augmentation in a combined vertical and horizontal defect. Alveolar ridge defect *(a)*. Tented-up augmentation volume 4.0 mm vertical and 4.3 mm horizontal (US Ustomed) *(b and c)*. Defect filled with a mixture of PRF and ABS + covered with collagen membrane (Bio-Gide, Geistlich Biomaterials) *(d)*. Tension-free wound closure *(e)*. Clinical situation 14 days postoperatively *(f)*. Clinical situation 6 months post-operatively *(g)*. Reentry, US covered with a small layer of soft tissue (resorption vertical 0.5 mm, horizontal 0.0 mm) *(h)*. Clinical situation after removing the US, with inserted implants (Astra EV D 3.6 mm, L 9.0 mm; Dentsply Sirona) in a completely regenerated alveolar ridge *(i)*.

Statistical analysis

To reduce the bias of multiple augmentations in the same patient, the patient's first augmentation site was chosen for statistical analysis. Quantitative values are presented as mean, standard deviation (SD), and minimum and maximum, as well as quartiles. Boxplots and scatterplots with linear regression lines are used for graphical representations. For statistical testing, *t* tests for independent samples were used for two-group comparisons (type I error, $\alpha = .05$). All calculations were made with SPSS Statistics for Windows (IBM, version 29.0).

Results

In total, 228 patients (102 men and 126 women) were treated with alveolar ridge augmentation by using the umbrella technique, and were retrospectively analyzed. One to eight screws were used per site. The mean age at time of augmentation was 52.32 ± 15.11 years (men) and 56.71 ± 13.06 years (women). Regarding smoking, 199 were nonsmokers, 10 smoked less than cigarettes 10 per day, and 19 smoked more than 10 per day. The location of the augmented region was 57.89% (n = 132) in the maxilla and 42.11% (n = 96) in the mandible. The defects aug-

mented were vertical (25), horizontal (167), and combined defects (36). The dimensions for vertical augmentation ranged between 1 and 12 mm (mean, 5.47 mm; median, 5.00 mm; SD, 2.08 mm), and for horizontal augmentation between 2 and 10 mm (mean, 5.10 mm; median, 5.00 mm; SD, 1.48 mm). In total, 463 USs were placed. Most (89%) of the defects could be augmented with three or less USs.

Analysis 1

Early exposure (US1+US2+US3)

Early exposure (wound dehiscence in the first 2 weeks after surgery) occurred in n = 39 (17.10%) cases. Age ($P = .208$), soft tissue thickness ($P = .891$), smoking habit ($P = .202$), grafting material ($P = .703$), and the location of the site of augmentation in the maxilla or mandible ($P = .837$) had no significant influence on the risk of an early exposure.

Male sex ($P = .02$), a vertical defect component ($P = .000$), and a greater extent of vertical augmentation ($P = .048$) showed a significantly higher risk for early exposure.

Late exposure (US1+US2)

Late exposure (wound dehiscence occurred after the first 2 weeks after surgery) was detected in n = 15 (6.98%) cases. Age ($P = .908$), sex ($P = .203$), soft tissue thickness ($P = .696$), smoking habit ($P = .252$), and the location of the augmentation ($P = .371$) had no significant influence on the risk of a late exposure. The use of AB/XBS seems to correlate with a lower risk (Table 1).

Table 1 Influence of augmentation material on late exposure

Augmentation material	Late exposure		Total
	No	Yes	
AB	10	1	11
ABS	142	13	155
AB/XBS	48	1	49
Total	200	15	215

As for early exposures, a vertical component of the defect bore a significantly higher risk for late exposure ($P = .024$), independent of the extent of the US-vd ($P = .214$). The risk for a premature screw removal was significantly lower if the defect had only a horizontal component ($P = .000$). However, the extent of horizontal augmentation increased the risk for a late exposure ($P = .040$) significantly.

Analysis step 2 (US1)

Resorption rate, bone gain, and TPI could only be measured or calculated in cases without any premature screw removal, otherwise, the immeasurable possibly poor performance at the missing screw could lead to incorrect interpretation of the result as good.

Resorption rate

In the group US1, the mean extent of augmentation was 5.01 ± 1.49 mm for the horizontal (US-hd) (n = 183) and 5.32 ± 1.88 mm for vertical (US-vd) (n = 44) component. The mean resorption rate was horizontally (US-hnb) 0.85 ± 0.91 mm and vertically (US-vnb) 1.21 ± 1.03 mm.

Age (h[$P = .543$], v[$P = .607$]), sex (h[$P = .475$], v[$P = .242$]), smoking habit (h[$P = .569$], v[$P = .371$]), extent of horizontal ($P = .318$) or vertical ($P = .983$) augmentation, defect morphology, and soft tissue thickness ($P = .962$ for horizontal and $P = .574$ for vertical resorption) had no significant influence on the resorption rate.

Using an AB/XBS showed less, but not significantly less vertical resorption (mean 0.72 ± 0.83 mm) compared to ABS (mean 1.33 ± 1.05 mm) ($P = .113$). In relation to the horizontal resorption rate, the GMs showed no significant difference ($P = .953$).

Augmentations in the maxilla (0.71 ± 0.91 mm) resulted in significantly less horizontal resorption than those in the mandible (1.07 ± 0.87 mm) ($P = .009$).

In case of early exposure, the horizontal resorption rate was not influenced ($P = .635$), but there was significantly more vertical resorption (mean 1.88 ± 0.96 mm with and 1.01 ± 0.97 mm without early exposure) ($P = .023$).

A late exposure correlated significantly with both greater horizontal (1.31 ± 0.45 mm; $P = .027$) and greater vertical (0.97 ± 0.25 mm; $P = .030$) resorption.

Implants could be placed in any of the augmented sites despite the resorption that had occurred.

Bone gain

The mean bone gain was 4.23 ± 1.69 mm (n = 183) for the horizontal and 4.11 ± 1.99 mm (n = 44) for the vertical dimension. The older the patient, the less horizontal ($P = .041$) but more vertical ($P = .024$) bone gain was detected. Regression analysis,

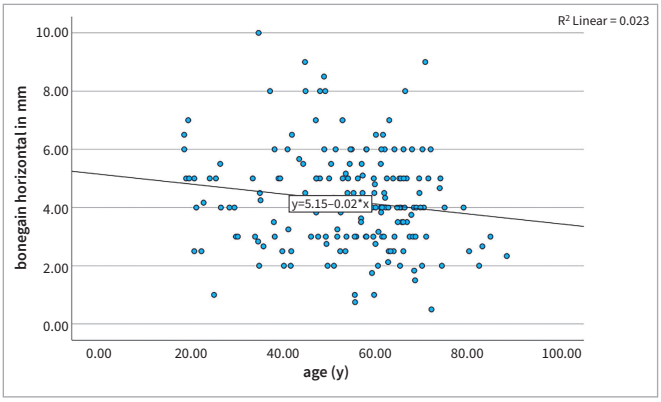


Fig. 5 Regression analysis bone gain horizontal – age.

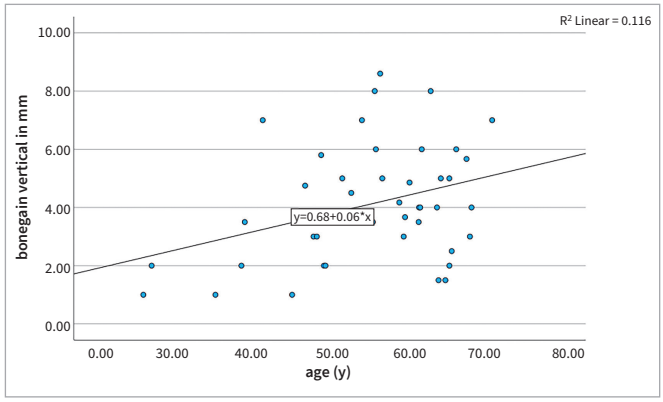


Fig. 6 Regression analysis bone gain vertical – age.

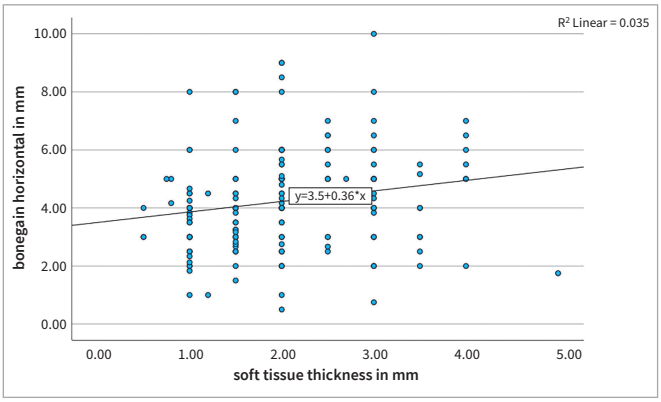


Fig. 7 Regression analysis bone gain horizontal – soft tissue thickness.

however, showed an inhomogenous distribution (Fig. 5 and 6). This suggests a weak correlation with a moderate risk of bias.

Sex had no significant influence on the bone gain. Smoking led statistically to more horizontal bone gain ($P = .022$) and had no influence on vertical bone gain ($P = .543$). Considering the size of the individual groups, there was an uneven distribution and thus a low significance of the results.

Thicker soft tissue resulted in greater horizontal bone gain ($P = .037$) (Fig. 7). For the vertical dimension, the level of significance was not reached, but a tendency was also seen here ($P = .096$).

In the maxilla, more horizontal bone gain in comparison to the mandible was detectable ($P = .000$). For vertical bone gain, no such significant effect was seen ($P = .166$), but there was a tendency for more vertical bone gain in the mandible.

Using an ABS seemed to gain more bone than AB or AB/XBS for the horizontal component ($P = .007$) but made no difference in terms of the vertical component ($P = .923$).

The presence of a vertical component of the defect morphology resulted in significantly less horizontal bone gain ($P = .042$). On average, this was 0.81 mm less. The more bone was augmented in the vertical or horizontal direction, the more bone gain was achieved ($P = .000$) (Fig. 8 and 9).

An early exposure had no significant influence on the bone gain (h[$P = .772$], v[$P = .594$]). Late exposure was correlated with less vertical bone gain (mean 1.67 mm; $P = .035$). However, late exposure had no influence on the horizontal bone gain ($P = .668$).

Target performance index

When no screw had to be removed prematurely, the TPI between augmented and newly formed bone was on average 75.90% for the vertical and 82.35% for the horizontal component of augmentations (Table 2).

Age, sex, smoking habit, and soft tissue thickness had no statistical influence on the TPI. The extent of horizontal augmentation significantly influenced the percentage TPI horizontally ($P = .012$). The other dimensions of the augmentation had no influence on TPI. To evaluate the extent of augmentation and its correlation to soft tissue thickness and TPI, a split was made at the median (extent of augmentation: 5.00 mm / soft tissue thickness: 2.00 mm). An early exposure was linked to a worse TPI in general, and the mean difference of 0.87 in absolute vertical TPI was significant ($P = .016$). Late exposure was correlated with a highly significant change in TPI. If a late exposure was detected, the mean TPI was 24.9% worse for the vertical and 17.22% worse for the horizontal dimension (Table 3).

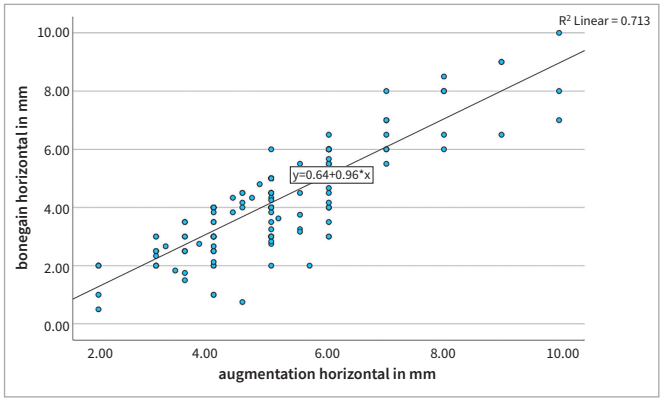


Fig. 8 Relationship between extent of horizontal augmentation and horizontal bone gain – regression analysis.

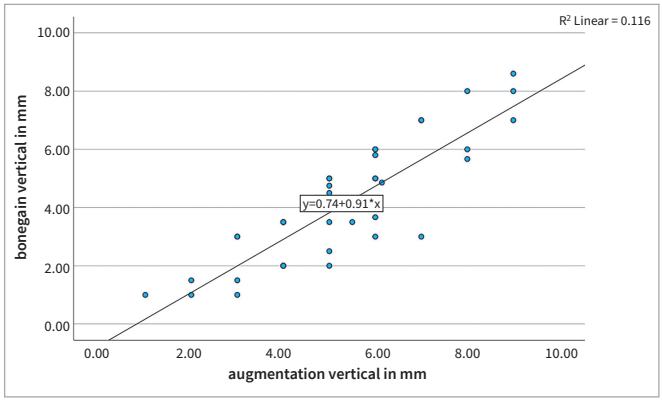


Fig. 9 Relationship between extend of vertical augmentation and vertical bone gain – regression analysis.

Analysis step 2 (US2)

In cases of a partial premature screw removal because of exposure (n = 14), implant placement was always possible; eight sites needed a very limited second augmentation.

Analysis step 2 (US3)

All USs had to be removed prematurely at 13 sites due to exposure. In three of these cases, the implant placement was possible without any further augmentation. For nine sites a small second augmentation was required, but implant placement was possible. One patient refused further treatment after the complications occurred.

Early implant loss

Three out of 274 implants placed after augmentation in a second stage (three patients) had to be removed before placement of the prosthetic restoration because of infection. After healing in two cases, new implants were placed. All these implants are still in function.

Late implant loss

Until September 2023 one implant was lost after placement of the prosthetic restoration.

Bone density

The bone density in these cases was D1 for 11, D2 for 73, D3 for 157, and D4 for 33 implants.

Insertion torque

The insertion torque of the implants placed in the augmented bone was 29.59 ± 19.38 Ncm.

Discussion

Horizontal and especially vertical alveolar ridge augmentation is a challenging surgical procedure. During recent decades, plenty of augmentation techniques have been suggested and scientifically investigated to achieve adequate bone volume and quality. The aim of the present study was to evaluate the efficacy of a technique for alveolar ridge augmentation by using novel umbrella tenting screws.

Wound dehiscences during healing increase the risk of infection and are a common and serious complication. In particular, exposed nonresorbable membranes or meshes often require removal, and even a partial or total loss of the augmented volume happens frequently. A randomized clinical trial from Cucchi et al[13] reported that 10% of sites augmented with a guided bone regeneration (GBR) procedure using nonresorbable membranes showed major complications with removal of the membrane. This affected the amount of newly formed bone or the success of the bone augmentation surgery. The GBR procedure using a titanium mesh showed 15.8% major complications, and the removal of the mesh was necessary in 5.3% of the cases.[13] In the present cohort, all the 54 cases that experienced wound dehiscences (39 early and 15 late exposures; 24.08% of the augmented sites) could be restored with implants in the desired position. If the screw head was exposed, patients were able to brush and clean the exposed metal. If the screw head was exposed partially, especially in mobile tissue the US were removed prematurely (group US2/US3, 27 cases, 42 USs) with no further clinical disadvantage for the planed implant placement.

In total, 17 sites needed a small secondary augmentation. Le et al[14] described a tenting method for vertical defects by using

Table 2 Descriptive evaluation of the TPI

Parameter		TPI vertical percentage	TPI horizontal percentage	TPI vertical absolute	TPI horizontal absolute
Number of implants	Valid	44	183	44	183
	Missing	157	18	157	18
Mean (%)		75.90	82.35	−1.21	−0.84
Median (%)		78.42	84.21	−1.00	−0.75
SD (%)		20.54	19.00	1.03	0.91
Minimum (%)		33.33	16.67	−4.00	−3.75
Maximum (%)		100.00	120.00	0.00	1.00

titanium screws with a small head. In their study, 13.3% of screws showed a wound dehiscence and 33% needed a second augmentation before the implant could be placed at the desired position.[14] Deeb et al[15] reported a dehiscence rate of 4.11%, with a possible implant placement rate of 97% after 6 months, by using small-headed tenting screws. Although the dehiscence rate in the present study was considerably higher due to higher volumes of augmentation, the outcome regarding the subsequent possibility of implantation was significantly better.

The reason for the high rate of early exposures in the present study might be found in the study protocol. Every not-perfect wound closure after 2 weeks was classified as an early exposure. This did not directly lead to exposure of the membrane or even GM. In many cases, the exposed collagen membrane fulfilled its barrier function, protected the graft, and the superficially disinfected dehiscence closed after a short time.

The larger diameter of the screw head seems to be more efficient in generating a stable situation for bone regeneration. To prevent such an exposure, both correct US positioning and accurate and noninvasive soft tissue handling in terms of tension-free wound closure and maintenance of blood supply is mandatory. GMs covered by a membrane hinder the blood supply having origin from the bone.

As the periosteum must be cut in order to coronally advance, the flap thickness seems to have a major impact on the amount of remaining blood supply and thus on wound healing.[16] In the present study, the flap thickness was assessed with a periodontal probe, and the thickness and exposure rate were correlated. Differences in soft tissue thickness did not impact the risk of complications. A statistically insignificant correlation was found between thicker soft tissue and increased bone gain. Wound healing is concurrent with a decreasing blood perfusion rate immediately after surgery, followed by hyperemia, both favoring exposure rate.[17]

Additionally, the rate of complications is influenced by the amount of stretching and tension in the flap.[18] Vertical augmentation requires a more extended flap mobilization. In the present study, cases with a vertical augmentation component showed a higher prevalence of early ($P = .000$) and late exposure ($P = .024$). The extent of the vertical component was only relevant for early exposure ($P = .048$). This is in line with the results of the Consensus report of the 15th European Workshop on Periodontology on Bone Regeneration, which reported a higher risk of complications when performing vertical augmentation.[4] Furthermore, the vertical component increases the risk for premature screw removal. In case of an early exposure, the horizontal resorption rate was not significantly influenced ($P = .635$). Vertical augmentations with an early or late exposure and horizontal augmentations with a late exposure showed significantly higher resorption at the US head ($P < .05$). However, early exposure did not have a negative impact on the amount of bone gain (h[$P = .772$], v[$P = .594$]). In cases with late exposure, only the vertical bone gain was negatively influenced (h[$P = .668$], v[$P = .035$]).

A systematic review and meta-analysis on the effectiveness of lateral bone augmentation reported significantly more gain for not-exposed sites.[19] The reason for the only partially negatively influenced bone gain was found in the extent of augmentation in the present study, as these cases had a higher extent of augmentation. However, statistically, greater augmentation was linked to an increased risk of exposure and at the same time greater bone gain. Therefore, bone gain seems not to be a good reference parameter for making a statement about the influence of dehiscence on the result of augmentation. A better reference could be the TPI. The TPI showed significantly worse results in the event of an exposure in the present study. The horizontal TPI did not reach the level of significance, but it did show a tendency ($P = .080$). The TPI was 75.90% for the vertical

Table 3 Influence of late exposure on TPI

Late exposure		n	Mean	SD	SE	*P* (*t* test for equality of means)
Target performance index vertical percentage	No	39	78.73	19.21	3.08	.036
	Yes	5	53.83	18.51	8.28	
Target performance index horizontal percentage	No	176	83.01	18.65	1.41	.080
	Yes	7	65.79	21.59	8.16	
Target performance index vertical absolute	No	39	−1.10	1.02	0.16	.030
	Yes	5	−2.07	0.69	0.31	
Target performance index horizontal absolute	No	176	−0.79	0.87	0.07	.026
	Yes	7	−2.11	1.19	0.45	

SE, standard error of the mean.

and 82.35% for the horizontal augmentation components. In order to generate sufficient vertical bone, a more pronounced over-augmentation should be considered. However, this would mean more difficult soft tissue management and a higher risk of complications, as explained above.

When using AB/XBS, there was a tendency for less late exposure and less vertical resorption, but the horizontal bone gain was significantly higher with ABS. Therefore, a mixture of ABS and XBS might be useful. With a low quality of evidence, the meta-analysis by Naenni et al[20] reported less resorption after lateral augmentation when adding XBS to AB. In the present study this advantage was not found in horizontal components. A possible explanation for this could be that studies with xenogeneic blocks were included in the analysis by Naenni et al.[20] Often, the use of AB is postulated, without clear evidence in the literature. Meloni et al[21] reported good results for ridge augmentation by using a 1:1 ratio of particulate XBS and AB in a case study. In the present study, worse results were not found when using only ABS without adding any AB. Similarly good results were reported by Farias et al,[22] from the use of a mixture of ABS and leukocyte- and platelet-rich fibrin with tenting screws in horizontal bone augmentation. They even reduced the healing period to 4 months and reached a mean bone gain of 4.2 ± 1.26 mm.[22] A systematic review and meta-analysis on the efficacy of lateral bone augmentation showed a mean clinical bone gain of 3.45 ± 1.18 mm.[20] Thoma et al[23] measured a median ridge width increase from 4.0 mm (Q1 = 2.0 mm; Q3 = 4.0 mm) (xenogeneic) and 2.0 mm (Q1 = 2.0 mm; Q3 = 3.0 mm) (autogenous) to 7.0 mm (Q1 = 6.0 mm; Q3 = 8.0 mm) (xenogeneic) and 7.0 mm (Q1 = 6.0 mm; Q3 = 8.0 mm) (autogenous) at 4 months (intergroup $P > .05$) for block augmentations with in mean less than 0.6 mm of resorption.

Another meta-analysis from 2018 reported a mean bone gain of 3.61 ± 0.27 mm for guided bone regeneration (GBR) in horizontal ridge augmentations.[24] Cesar Neto et al[25] showed a positive effect on GBR technique when using an additional tenting screw similar to the US. With CAD/CAM-produced titanium meshes, Sagheb et al[7] reached a mean horizontal bone gain of 5.5 ± 1.9 mm, and a mean vertical bone gain of 6.5 ± 1.7 mm. A cases series using titanium-reinforced polytetrafluoroethylene (e-PTFE) membranes and particulate autografts reported a mean vertical bone gain of 5.5 ± 2.29 mm.[6] Mean combined crestal remodeling was 1.01 ± 0.57 mm at 12 months.[6] A systematic review and meta-analysis on the effectiveness of vertical ridge augmentation interventions confirmed a significant vertical bone gain for all investigated treatment approaches, with a weighted mean effect of 4.16 mm; 95% confidence interval (CI) 3.72 to 4.61.[26] Soldatos et al[27] reported vertical bone gain ranging from 4.0 to 7.9 mm in a case series by using tenting screws.

In the present study, a mean bone gain of 4.23 ± 1.69 mm horizontally and 4.11 ± 1.99 mm vertically was reached, with a mean resorption of 0.85 ± 0.91 mm for horizontal and 1.21 ± 1.03 mm for vertical augmentations. However, the regression analysis showed that there was no limit in horizontal or vertical direction. The greatest extent of augmentation was 10 mm for a horizontal component, which led to a mean bone gain of 8.33 ± 1.53 mm, and 9.00 mm for a vertical component with a mean bone gain of 7.87 ± 0.81 mm. The more augmentation was carried out, the more bone was gained. However, at the same time, the risk for early exposure increased. The absolute change of ridge bone width (BW) was not measured in the present study, but the results of the meta-analysis by Naenni et al[20] on lateral bone augmentation BW at baseline (prior to augmentation) was significantly inversely correlated with the obtained BW gain, which indicates that the thinner the alveolar process at baseline, the more BW gain could be achieved.[20] Due to the fact that a thinner BW needs a greater augmentation, this cor-

relates to the statement that "the more augmentation was carried out, the more bone was gained," and shows, as discussed above, the low informative value of the bone gain with regard to the statement about the effectiveness of an augmentation method. The present results showed a greater horizontal bone gain for the maxilla and greater vertical bone gain for the mandible. In the present authors' opinion, the reason for these unexpected results could be found in the needed extent of augmentation. The mean horizontal component was greater in the maxilla and the mean vertical component was greater in the mandible. Possible there is no difference in the potential for bone gain, but a difference in alveolar ridge resorption after tooth extraction in the maxilla and mandible. A recent systematic review and meta-analysis on postextraction dimensional changes does not provide any information about a different resorption behavior in the maxilla and mandible.[28] A recently published systematic review and network meta-analysis showed the need for lateral bone augmentation in cases of dehiscence or fenestration defects during simultaneous implant placement.[29] Using an additional US does stabilize the augmentation. Understanding the efficacy of the umbrella tenting technique in cases with simultaneous implant placement is the aim of ongoing studies. Further studies are needed to analyze a minimum healing period before reentry can be performed.

To provide information about the quality of gained bone, the present study assessed the insertion torque, bone density (D1 to D4) during pilot drilling, and the number of early failures of implants as surrogate parameters. Three out of 274 implants were lost. Numbers of early implant loss were published by Derks et al,[30] with 1.4%, and Lin et al,[31] with 0.62%. The present rate of early loss of implants is in line with the published retrospective literature examining more than 30,000 implants with and without prior augmentation. Trisi and Rao[32] reported that surgeons' hand feeling allowed good or poor bone density to be distinguished, in comparison to a histomorphometric evaluation. Rokn et al[33] showed that surgeons' tactile sense had a significant correlation with bone density in preoperative CT scans. As insertion torque correlates to the design of the implants, morphology, drilling protocol, and bone quality, it seems to be a relatively weak indicator of good bone quality. Nevertheless, the present results are in line with the published literature even for nonaugmented bone.[34-36] The assessed insertion torques, bone density, and failure rates of placed implants in the present data are in line with the published literature and thus are a predictable surrogate for good bone quality.

Conclusion

Within the limitations of this study, being retrospective and having no control group, the results show that augmentation with umbrella tenting screws is a safe and predictable procedure for large vertical and horizontal ridge augmentations. As this was a retrospective data analysis, reflecting everyday life in a specialized practice, no histologic analysis was available, and the described cofounders such as different GMs or implant types must be noted. With a mean resorption rate of 0.85 mm for the horizontal and 1.21 mm for the vertical component, an overcorrection of the defects should be performed. Wound dehiscence and premature removal of the US does not cause major complications, and in all augmented areas implant placement could be performed at the designated position. A low number of early and late implants lost indicates stable osseous conditions after US augmentation. To make different bone augmentation techniques comparable, the target performance index was introduced. On the basis of the present data, a mean percentage of 75.90 ± 20.54 TPI for vertical and 82.25 ± 16.67 TPI for horizontal components could be reached, suggesting the necessity for some over-augmentation to reach the planned goals.

Disclosure

Markus Schlee indicates an economic conflict of interest. He profits economically from the sale of the US. All other authors state that they have no conflicts of interest regarding the submitted article.

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