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**Long-term clinical and radiographic results after treatment or no treatment
of small buccal bone dehiscences at posterior dental implants: A
randomized, controlled clinical trial**

Waller, Tobias ; Herzog, Milan ; Thoma, Daniel Stefan ; Hüsler, Jürg ; Hämmerle, Christoph H F ;
Jung, Ronald Ernst

Abstract: Aim: To test whether or not buccal vertical bone dehiscences (5 mm) around posterior implants left for spontaneous healing (SH) result in the same clinical and radiologic outcome as dehiscences treated with guided bone regeneration (GBR) at 7.5 years after implant placement (IMPL). Materials and methods: Twenty-two patients receiving 28 posterior implants with a small non-contained buccal bone dehiscence (5 mm) were randomly assigned to the SH or the GBR group. Implants were loaded at 6 months. Clinical parameters (probing depths, sulcus bleeding index, plaque index) and approximal marginal radiographic bone levels were assessed regularly up to at least 6.8 years. The vertical extension of the dehiscences was measured clinically at IMPL and abutment connection and radiographically on cone beam computed tomographys at a mean follow-up time of 7.5 years. Results: Twenty patients with a total of 26 implants were recalled at 7.5 years (9.1% dropout). The implant/crown survival rates were 100% in both groups. Stable peri-implant tissues were observed in both groups showing only minimal signs of inflammation. During the entire study period (IMPL-7.5-year follow-up), the median buccal vertical bone gain measured 1.61 mm for the GBR group and 0.62 for the SH group showing no significant difference between the groups. Also, at 7.5 years, the median approximal marginal bone levels (GBR: 0.53; SH: 0.68) were not significantly different between the two groups ($p = .61$) while the remaining median buccal vertical dehiscences were larger in the SH group (2.51 mm) compared to the GBR group (1.66 mm; $p = .02$). Conclusions: Implants with small non-contained buccal bone dehiscences exhibited high implant survival rates and healthy peri-implant tissues at 7.5 years. In the GBR group, the buccal vertical bone levels were higher compared to the SH group but remained stable over the entire study period for both treatments. Keywords: bone substitute; dental implant; guided bone regeneration; small buccal defects; spontaneous healing. © 2020 John Wiley Sons A/S. Published by John Wiley Sons Ltd.

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Long-term clinical and radiographic results after treatment or no treatment of small buccal bone dehiscences at posterior dental implants - A randomized, controlled clinical trial.

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Key words: bone substitute, dental implant, guided bone regeneration, small buccal defects, spontaneous healing

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Abstract

Aim: to test whether or not buccal vertical bone dehiscences (≤ 5 mm) around posterior implants left for spontaneous healing (SH) result in the same clinical and radiological outcome as dehiscences treated with guided bone regeneration (GBR) at 7.5 years after implant placement.

Materials and methods: 22 patients receiving 28 posterior implants with a small non-contained buccal bone dehiscence (≤ 5 mm) were randomly assigned to the SH or the GBR group. Implants were loaded at six months. Clinical parameters (PD, SBI, PI) and approximal marginal radiographic bone levels were assessed regularly up to at least 6.8 years. The vertical extension of the dehiscences was measured clinically at implant placement and abutment connection and radiographically on CBCTs at a mean follow up time of 7.5 years.

Results: 20 patients with a total of 26 implants were recalled at 7.5 years (9.1% drop-out). The implant/crown survival rates were 100% in both groups. Stable peri-implant tissues were observed in both groups showing only minimal signs of inflammation. During the entire study period (implant placement - 7.5 years follow-up) the median buccal vertical bone gain measured 1.61 mm for the GBR group and 0.62 for the SH group showing no significant difference between the groups. Also, at 7.5 years, the median approximal marginal bone levels (GBR: 0.53; SH: 0.68) were not significantly different between the two groups ($p=0.61$) while the remaining median buccal vertical dehiscences were larger in the spontaneous healing group (SH) (2.51 mm) compared to the GBR group (1.66 mm) ($p=0.02$).

Conclusions: Implants with small non-contained buccal bone dehiscences exhibited high implant survival rates and healthy peri-implant tissues at 7.5 years. In the GBR group, the buccal vertical bone levels were higher compared to the SH group but remained stable over the entire study period for both treatments.

Introduction

In order to obtain favourable conditions for dental reconstructive treatment, implants are supposed to be placed in a prosthetically driven approach. Thus, backward planning often leads to implant locations outside of the bony envelope resulting in buccal bone dehiscence ([Hammerle, Tarnow, 2018](#)). These dehiscences can successfully be treated with guided bone regeneration (GBR) employing membranes, bone grafts and bone substitute materials ([Hammerle, Karring, 1998](#)). The concept of GBR for different defect dimensions and locations has been proven in various clinical trials and systematic reviews ([Chiapasco, Zaniboni, 2009](#); [Clementini, Morlupi, Canullo, Agrestini, Barlattani, 2012](#); [Zitzmann, Scharer, Marinello, 1999](#)) and is widely used in clinical practice.

Notwithstanding, only few studies addressed the question whether GBR applied to small buccal vertical bone dehiscences (≤ 5 mm) in the posterior area results in a clinical benefit ([Sanz-Sanchez, et al., 2018](#); [Schropp, Wenzel, Spin-Neto, Stavropoulos, 2015](#)). Notably, there are some clinical studies investigating the stability of implants with buccal vertical bone dehiscences left for spontaneous healing ([Carmagnola, Araujo, Berglundh, Albrektsson, Lindhe, 1999](#); [Palmer, et al., 1994](#)). The studies showed no effect on the short-term implant survival.

In a randomized controlled clinical trial, Jung et al ([Jung, et al., 2017](#)) analyzed the defect morphology after implant placement and at the time of reentry at abutment connection. It could be shown that implants in the spontaneous healing group exhibited significantly more vertical bone loss at the buccal aspect within the first 6 months after implant placement compared to the GBR group. With this lack of buccal bone, exposure of rough implant surfaces is generally feared thereby compromising peri-implant health ([Rasmusson, Meredith, Sennerby, 1997](#)). In a 4-year observational study, it has been shown that residual buccal vertical defect depth > 1 mm after implant placement is correlated with peri-implantitis ([Schwarz, Sahm, Becker, 2012](#)). However, this topic remains controversial.

Therefore, the aim of the current study was to test whether or not small buccal vertical bone dehiscences (≤ 5 mm) around posterior implants left for spontaneous healing (SH) result in the same clinical and radiologic outcomes as dehiscences treated with guided bone regeneration (GBR) at 7.5 years after implant placement.

Material and Methods

Study Design

The present study was designed as a 7.5-year follow-up of a prospective, single-center, randomized, controlled clinical trial, encompassing 22 patients in good general health and enrolled in comprehensive dental care and requiring implant treatment with small buccal vertical bone dehiscences (≤ 5 mm) around implants ([Jung, et al., 2017](#)).

Patient recruitment, treatment and follow-ups were performed in a private practice (M.H.). The clinical study protocol and all procedures and materials were approved by the local ethical committee of the Canton of Zurich (KEK) before the start of the study (KEK-ZH-Nr.: 2016-02053). Informed consent was obtained from all patients before any study procedures were performed. All data up to the eighteen months follow-up visit (Fig. 1) has been obtained and published in an earlier study ([Jung, et al., 2017](#)).

Surgical intervention, randomization, reentry, prosthetic reconstruction

The interventions were described in detail in the eighteen-months follow-up study ([Jung, et al., 2017](#)). The timeline of the performed treatments and measurements can be seen in Fig. 1. In brief, twenty-eight implants with small non-contained buccal vertical bone dehiscences of no more than 5 mm were included in the study.

Inclusion criteria were defined as follows: good health, enrolled in recall program, need of at least one dental implant in the posterior area, given informed consent. Exclusion criteria were defined as follows: pregnancy, no primary stability of the implant, absence of a buccal dehiscence defect or a vertical defect size of > 5 mm.

Due to the lack of data, a power calculation could not be performed. Implant placement was performed either delayed (six weeks - six months after extraction of the tooth) or late (> 6 months after extraction).

All patients received antibiotics (2 x 750 mg Clamoxyl®; GlaxoSmithKline AG, Münchenbuchsee, Switzerland) and analgesics/antiphlogistics (500 mg Mefenacid®; Streuli Pharma AG, Uznach, Switzerland) presurgically. The implant site was prepared

according to the Camlog System protocol. CAMLOG® SCREW-LINE implants (Camlog Biotechnologies AG, Basel, Switzerland) were inserted. All implants were located in posterior sites (Table 1).

After defect measurement at implant placement (IMPL) (Fig. 2a), the patients were randomized with prepared envelopes to either receive GBR (deproteinized bovine bone mineral + collagen membrane) or to heal spontaneously (SH). After six months of submerged healing, in a reentry surgery (REENTRY), buccal vertical bone dehiscences were again measured with a calibrated probe (Fig. 2a). After initial healing and impression, the prosthetic reconstructions were inserted comprising 20 Ti-Base abutments and 8 customized gold abutments. Twenty-four implants received single crowns and four implants received three-unit bridges. Restorations were either cemented (12 implants) or screw retained according to the clinical situation.

Follow-up examinations

The following clinical and radiographic assessments were performed at 3, 6, 12, 18 months and 7.5 years after insertion of the crowns.

Clinical measurements

1. Implant and crown survival
2. Peri-implant probing depths (PD) (six sites per implant) recorded to the nearest millimeter with the periodontal probe (UNC-15, standardized force of 0.2-0.3 N, examiner M.H. was calibrated in advance).
3. Sulcus bleeding index (SBI) ([Muhlemann, Son, 1971](#)) (4 surfaces per implant)
4. Plaque index (PI) ([Silness, Loe, 1964](#)) (four surfaces per implant)

Radiographic measurements

1. Cone beam computed tomography (CBCT) analysis (FU-7.5Y)

CBCT evaluation of the buccal vertical bone dehiscences was performed as described in ([Jung, Benic, Scherrer, Hammerle, 2015](#)) the at 7.5 years follow-up (FU-7.5Y) only. CBCT images were acquired (3D eXam®, KaVo Dental, Biberich, Germany) using the following technical parameters: 120 kV, 5 mA beam current, field-of-view (FOV) diameter of 16 cm, FOV height of 4 cm, 360° rotation and voxel size of 0.125 mm. For the linear measurements of the three-dimensional dataset, the bucco-oral central section perpendicular to the implant axes was used (OsiriX® Imaging Software, Geneva, Switzerland).

1. Buccal vertical defect depth (A) measured from the implant shoulder to the first bone-to-implant contact and infrabony defect depth (B) measured from the buccal bone crest to the first bone-to-implant contact (Fig. 2b).
2. Horizontal Bone Thickness.: Thickness of the buccal bone 1 mm, 2 mm and 3 mm apical of the implant shoulder (Fig. 2b).

2. Approximal marginal bone level

Intraoral radiographs were taken at all follow-up visits starting 3 months after crown insertion with the long-cone paralleling technique centering the alveolar crest (Hawe X-ray film holder; Kerrhawe SA, Bioggio, Switzerland). The x-ray machine (X mind®, Aceton Germany GmbH, Düsseldorf, Germany) was set to 70 kV and 0.32 mA for the upper jaw and 0.25 mA for the lower jaw respectively. The film-based images (Kodak Ultraspeed, Rochester, USA) were scanned and digitalized (Epson Perfection V700 Pro Scanner, at 1200 dpi). Images were checked for sufficiency by the visibility of sharp implant threads. The approximal marginal bone levels (MBL = distance between the implant shoulder and the first bone-to-implant contact ([Buser, Weber, Bragger, Balsiger, 1991](#); [Weber, Buser, Fiorellini, Williams, 1992](#))) were calculated as the mean values of mesial and distal measurements (Image J, Version 1.44;

U.S. National Institutes of Health, Bethesda, MD, USA) Negative values represent bone levels coronal to the implant shoulder, positive value represent bone levels apical to the implant shoulder. Dimensions were calibrated using the implant diameter.

The primary endpoint was the median buccal vertical defect depth (distance first bone to implant contact and implant shoulder) at 6.8 - 8 years after implant placement.

Statistical analysis

Categorical data are described with counts and percentages. Continuous variables are described with mean and standard deviation (sd), and medians, the quartiles and the minimum and the maximum.

Since the data are not normally distributed and some are ordinal not continuous, nonparametric mixed linear models were applied for the statistical analysis and the model assumptions were checked, because of the dependence of the data within a patient. In case only one randomly chosen implant per patient was used for the analyses, the simpler nonparametric methods were applied. In particular, simple comparisons of the location of the measurements in the two independent groups were performed by Mann–Whitney U-test for this subset.

For the statistical analysis the software SAS 9.4 (SAS Institute Inc., Cary, NC, USA) was used.

Results

Patients

Out of twenty-two initially enrolled patients, twenty could be included in the present long-term follow-up study. Two patients with a total of two implants were lost to follow-up (one in the GBR group, one in the SH group) since they moved away and were not willing to travel for the follow-up visit. At surgery, the mean age was 56.2 (SD=10.98) years in the spontaneous healing group and 55.5 (SD=14.21) in the GBR group. The mean follow-up time was 7.5 years (min=6.8; max=8.0). 75% of the patients in the SH group and 90% of the patients in the GBR group were non-smokers (Table 2).

Implant survival

The implant survival rate at 7.5 years was 100%, revealing no serious biological or technical complications (Table 2).

Peri-implant probing depth (PD), sulcus bleeding index (SBI), Plaque index (PI)

All peri-implant measurements including PD, SBI and PI performed at three, six, twelve, eighteen months and 7.5 years after reentry surgery (REENTRY) demonstrated stable peri-implant tissues with no statistically significant differences between the SH and the GBR group for the above-named parameters (Fig. 3-5).

For the mid-buccal PD measurement specifically (location of the buccal defect) the mean PD values in the GBR group amounted to a mean of 1.8 mm (SD=0.84) and in the SH group to a mean of 2.1 mm (SD=0.73).

In the GBR group seven of thirteen implants showed at least at one site bleeding on probing (BOP); in the SH group eleven of fourteen were BOP positive representing the presence of mucositis. Peri-implantitis was found at none of the implants.

Buccal vertical defect change (measured clinically and on CBCT)

Based on clinical (implant placement (IMPL) and reentry surgery (REENTRY)) and radiographic measurements in the CBCT (FU-7.5Y) the median buccal vertical defect change from IMPL to REENTRY amounted to a gain of 1.00 mm (Q1: 0.50 mm/Q3: 3.00 mm) in the GBR group and to 0.00 (Q1: -1.50 mm/Q3: 0.50 mm) in the SH group (Table 3). During the entire study period (IMPL to FU-7.5Y) the buccal vertical defect change amounted to a buccal vertical gain of 1.61 mm (Q1: 1.01 mm/Q3: 3.09 mm) for the GBR group and 0.62 (Q1: -2.53 mm/Q3: 2.52 mm) for the SH group (Table 3). For the period between REENTRY and FU-7.5Y the buccal vertical defect change was 1.09 mm (Q1: -0.85 mm/Q3: 1.67 mm) for the GBR group and 0.72 (Q1: -0.46 mm/Q3: 2.52 mm) for the SH group (Table 3). The differences between the groups were not statistically significant at all analysed timepoints (IMPL, REENTRY, FU-7.5).

Radiographic defect dimensions (measured on CBCT)

At the FU-7.5Y the median buccal vertical defect depth (distance first bone to implant contact and implant shoulder) was 1.66 mm (Q1: 0.85 mm/Q3: 2.03 mm) for the GBR group and 2.51 (Q1: 1.88 mm/Q3: 5.53 mm) for the SH group (Table 4). The difference between the groups was statistically significant ($p=0.0192$). The buccal bone thickness in the GBR group was significantly different from the SH group at all measured levels (1 mm, 2 mm, 3 mm apical from implant shoulder). The median buccal bone thickness 2 mm apically from the implant shoulder was 1.08 mm (Q1: 0.31 mm/Q3: 1.66 mm) for the GBR group and 0.00 mm (Q1: 0.00 mm/Q3: 0.71 mm) for the SH group ($p=0.0079$) (Table 4). Infrabony defect depths (Fig. 2b, B) at the FU-7.5Y were always 0 mm in both groups and hence not further analyzed.

Radiographic approximal marginal bone levels (measured on peri-apical radiograph)

At FU-7.5Y the GBR group showed comparable approximal marginal bone levels (median=0.55; Q1=0.41; Q3=0.63) to the SH group (median=0.59; Q1=0.49; Q3=1.00)

without statistically significant differences ($p=0.604$) (Table 5). This was in line with the measurements of the whole follow-up period.

Discussion

The present study assessing outcomes of implant therapy in sites with guided bone regeneration (GBR) of small buccal vertical bone dehiscences and sites left for spontaneous healing (SH) revealed: i) high implant survival rates without occurrence of peri-implantitis independent of the group (GBR vs SH); ii) small buccal vertical bone level changes over time without significant differences between the groups; iii) larger buccal vertical bone dehiscences in the spontaneous healing group (SH) compared to the GBR group at FU-7.5Y; iv) an higher buccal bone thickness around implants in the GBR group compared to the spontaneous healing group (SH)

The **survival rate** of the implants and crowns in the present study was 100% in both groups. This was comparable to the 97% survival rate reported in different meta-analyses of reconstructions on single implants over a 5 years period ([Jung, Zembic, Pjetursson, Zwahlen, Thoma, 2012](#); [Sailer, et al., 2018](#)).

With respect to the **buccal vertical bone level between surgery and reentry**, the GBR group showed a median gain of 1 mm whereas in the spontaneous healing group no additional bone gain could be observed. This difference was statistically non-significant. Interestingly, the effect of bone augmentation (1 mm buccal vertical bone gain) was lower than the bone gains found in previous studies applying the same materials and techniques ([Jensen, Terheyden, 2009](#); [Jung, Halg, Thoma, Hammerle, 2009](#)). In a recent systematic review a mean defect depths of 5.1 mm could be reduced to a mean of 0.9 mm by applying GBR procedures ([Thoma, Bienz, Figuero, Jung, Sanz-Martin, 2019](#)). It can be speculated that these differences are due to the different inclusion criteria. In the previous study from Jung et al. 2009 implants exhibiting dehiscences of <3 mm have been excluded, whereas in the present study implants with dehiscences of that size were included. Since the dehiscences were generally smaller, lower defect fills for the present study can be expected. In addition, the present study primarily included cases in the lower posterior jaw, where GBR is difficult to perform due to the mobility of the soft tissue, the shallow vestibulum and the possible graft

displacement caused by gravitation. The systematic review from Thoma et al. 2019 included different locations as well as different GBR techniques.

With respect to the **buccal vertical bone level over the entire study period** (IMPL to FU-7.5Y), a slight buccal vertical bone gain of 1.61 mm in the GBR group and 0.62 in the SH group can be observed. With regard to the bone measurements at reentry surgery (REENTRY) the values at FU-7.5Y indicate a bone gain in the GBR group that is stable and even shows a tendency to further increase over time (1mm at REENTRY vs. 1.61 mm at FU-7.5Y). However, these results have to be interpreted with caution since the technique used to measure the buccal vertical bone dehiscences differs from the timepoints at IMPL and at REENTRY (clinical measurements) compared to the FU-7.5Y examination (CBCT measurements). It has been shown that in CBCT images a thin buccal layer of bone is more likely to be underestimated ([Gonzalez-Martin, et al., 2016](#); [Liedke, et al., 2017](#)). Hence, it is very unlikely that the observed bone gain in the present study will be related to the change in methodology from clinical to radiographic measurements.

According to the present data **larger buccal vertical bone dehiscences in the SH group (2.51 mm) compared to the GBR group (1.66 mm)** can be observed at FU-7.5Y (Table 4). However, this statistically significant difference is not represented in the measurements assessing peri-implant health (Fig. 3-5). It has been postulated that bone augmentation procedures are beneficial in order to maintain peri-implant health ([Schwarz, Giannobile, Jung, Groups of the 2nd Osteology Foundation Consensus, 2018](#)). Further, it has been hypothesized that residual defect depth > 1 mm after implant placement is correlated with compromised peri-implant health ([Schwarz, et al., 2012](#)). However, based on the present study, a complete osseous coverage of the buccal implant surface might not be a prerequisite for high implant survival rates and absence of peri-implantitis at FU-7.5Y. In a previous retrospective study it was reported that in one third of the implant cases there was no radiographically detectable bone visible 7 years after immediate implant placement and GBR procedure ([Benic, et al., 2012](#)). Similar to the present study, it has been reported that independent of the presence or

absence of the buccal bone healthy peri-implant tissues and satisfying esthetics were observed even in the anterior zone ([Veltri, Ekestubbe, Abrahamsson, Wennstrom, 2016](#)). In contrast to the present study, the authors reported a small buccal soft tissue recession of 1 mm compared to sites with radiographically detectable buccal bone. In another study using a dog model an inverse relationship between bone and soft tissue thickness could be demonstrated using linear regression analysis ([Schwarz, Sager, Golubovic, Iglhaut, Becker, 2016](#)) . It has, therefore, been postulated that in situations where buccal vertical bone dehiscences are present, the lack of volume might be compensated by thickening of the mucosal layer.

A limitation of the present study is the small group of 22 patients that have been treated. The results have, therefore, to be interpreted with caution. Further, it is methodologically challenging to compare the clinically evaluated buccal vertical bone levels at the time of the surgery and reentry with the radiographically measured buccal vertical bone levels at the FU-7.5Y follow-up. The technique nevertheless has been used in previous studies ([Benic, Elmasry, Hammerle, 2015](#); [Benic, et al., 2012](#); [Jung, et al., 2015](#)) and was approved by the local ethics committee because the performance of a CBCT is considered to be less invasive than an additional reentry surgery. Moreover, approximal marginal bone levels were calculated as mean values which could underrepresent defects being present only at one side of the implant. The measurement is yet justified since there was no one-sided defect present in the population and further this is a standard measurement in clinical studies at implants.

A long-term study with larger study population has to be designed to rule out concerns regarding statistical power. Another limitation of the study is that in the GBR group the buccal vertical bone gain is generally relatively small when compared to earlier studies. This can be explained by the chosen dehiscences that were shallow. Moreover, all of the implants were inserted and treated in the lower posterior region. No recommendation to waive GBR procedures in the anterior region (esthetic zone) or in the presence of deep buccal vertical bone dehiscences can be given. Hence, the results cannot be generalized to all areas of the jaws.

Conclusion

Implants with small buccal bone dehiscences (≤ 5 mm) left for spontaneous healing or treated by means of GBR exhibited high implant survival rates and healthy peri-implant tissues. In sites applying GBR procedures the buccal vertical bone dehiscences could be effectively diminished and the buccal vertical bone level remained stable over the 7.5 years observation period. The spontaneous healing group exhibited larger buccal vertical bone dehiscences at reentry surgery (REENTRY), however, these buccal vertical bone dehiscences do not worsen up to FU-7.5Y. Taken together the results, GBR is a justified treatment for small buccal vertical bone dehiscences however the necessity for clinical success has to be questioned based on the current data.

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Figure Legends

Figure 1: Timeline of the clinical and study related procedures

Figure 2:

a: Clinical measurement at the time of implant placement (IMPL) and at reentry surgery (REENTRY); A: buccal vertical defect depth from implant shoulder to first BIC; B: infrabony defect depth.

b: Radiographic analysis at the FU-7.5Y. A: buccal vertical defect depth from implant shoulder to first BIC. 1 – 3 mm buccal bone thickness as distance from the implant surface to the most buccal bone perpendicular to the implant axis at 1, 2 and 3 mm apical from the implant shoulder.

Figure 3: Peri-implant probing depth [mm]: mean over all measurement sites (mean per implant) including standard deviations

Figure 4: Sulcus bleeding index: mean over all measurement sites (mean per implant) including standard deviations.

Figure 5: Plaque index: mean over all measurement sites (mean per implant) including standard deviations. Error bars were cropped at zero values.

Figure 6: Photographic documentation of the main treatment steps exemplary for both treatment groups.

Table 1: Frequency distribution of the implant positions for both groups.

Implant position	Treatment randomisation				Total	
	Spontaneous healing		Guided bone regeneration			
	Frequency	%	Frequency	%	Frequency	%
15	1	6.7%	0	0.0%	1	3.6%
16	2	13.3%	1	7.7%	3	10.7%
25	2	13.3%	0	0.0%	2	7.1%
26	1	6.7%	2	15.4%	3	10.7%
34	0	0.0%	1	7.7%	1	3.6%
35	1	6.7%	0	0.0%	1	3.6%
36	1	6.7%	5	38.5%	6	21.4%
37	2	13.3%	0	0.0%	2	7.1%
45	1	6.7%	1	7.7%	2	7.1%
46	4	26.7%	3	23.1%	7	25.0%
Total	15	100.0%	13	100.0%	28	100.0%

Table 2: Demographics

Variable		Total	GBR	SH
Number of patients		22	10	12
Age at surgery		55.9 (SD=12.24)	55.5 (SD=14.21)	56.2 (SD=10.98)
Gender	female	12 (54.5%)	4 (40%)	8 (66.7%)
	male	10(45.5%)	6 (60%)	4 (33.3%)
Smoking status	Non-smokers	18 (81.8%)	9 (90%)	9 (75%)
	< 20 cig./day	4 (18.2%)	1 (1%)	3 (25%)
Follow-up time [y]		7.5 (6.8-8.0)	7.4 (6.8-7.9)	7.5 (6.9-8.0)
Implant survival		28	13	15
Implant survival rate		100	100	100
Patients lost to follow-up		2	1	1

Table 3: Bone changes from implant placement to the reentry surgery after 6 months (IMPL – REENTRY), from implant placement to the 7.5 years follow-up (IMPL – FU-7.5Y) and from reentry surgery after 6 months to the 7.5 years follow-up (REENTRY – FU-7.5Y) (negative value = bone loss; positive value = bone gain; GBR=guided bone regeneration; SH=spontaneous healing); mixed models all implants included.

Variable	Group	N	Mean	SD	Min	Q1	Median	Q3	Max	p-value
Vert. Def. Change IMPL – REENTRY	GBR	13	1.49	2.06	-2.50	0.50	1.00	3.00	5.00	0.1309
	SH	15	-0.27	1.62	-4.00	-1.50	0.00	0.50	2.50	
Vert Def Change IMPL – FU-7.5	GBR	13	1.89	1.98	-1.66	1.01	1.61	3.09	6.00	0.2824
	SH	15	-0.38	3.98	-8.71	-2.53	0.62	2.52	4.90	
Vert Def Change REENTRY - FU-7.5	GBR	13	0.40	1.59	-2.66	-0.85	1.09	1.67	2.10	0.7282
	SH	15	-0.11	3.60	-8.71	-0.46	0.72	2.52	3.50	

Table 4: Bone levels around implants at the FU-7.5Y; mixed models all implants included (buccal vertical bone dehiscence depth; buccal bone thickness at 1 mm, 2 mm and 3 mm apical from the implant shoulder; GBR=guided bone regeneration; SH=spontaneous healing).

Variable	Group	N	Mean	SD	Min	Q1	Median	Q3	Max	p-
Vert. Defect Depth [mm] FU-7.5	GBR	13	1.56	1.16	0.00	0.85	1.66	2.03	4.16	
	SH	14	3.83	3.36	-0.40	1.88	2.51	5.53	11.71	0
Horiz Bone 1 mm	GBR	13	0.59	0.77	0.00	0.00	0.15	1.01	2.30	
	SH	14	0.21	0.40	0.00	0.00	0.00	0.20	1.20	0
Horiz Bone 2 mm	GBR	13	1.03	0.88	0.00	0.31	1.08	1.66	2.61	
	SH	14	0.30	0.46	0.00	0.00	0.00	0.71	1.42	0
Horiz Bone 3 mm	GBR	13	1.51	1.00	0.00	0.71	1.68	2.13	3.28	
	SH	14	0.66	0.70	0.00	0.00	0.72	1.03	2.05	0

Table 5: Approximal marginal bone levels (3, 6, 12 M and 7.5Y; MBL=mean values calculated from distal and mesial radiographic approximal marginal bone levels as distance from the implant shoulder to first bone to implant contact; negative values represent bone levels coronal to the implant shoulder, positive value represent bone levels apical to the implant shoulder; GBR=guided bone regeneration; SH=spontaneous healing).

Variable	Group	N	Mean	SD	Min	Q1	Median	Q3	Max	p-value
MBL 3 M	GBR	9	-0.60	0.70	-1.55	-1.23	-0.60	0.00	0.25	0.3378
	SH	10	-0.28	0.70	-2.20	-0.38	0.00	0.00	0.25	
MBL 6 M	GBR	10	-0.48	0.74	-1.53	-1.15	-0.31	0.00	0.75	0.4011
	SH	10	-0.23	0.76	-2.18	-0.18	-0.04	0.00	0.80	
MBL 12 M	GBR	10	-0.38	0.66	-1.20	-1.00	-0.35	0.08	0.90	0.2149
	SH	11	-0.05	0.35	-0.65	-0.28	0.00	0.00	0.78	
MBL 7.5 Y	GBR	10	0.55	0.33	0.08	0.41	0.53	0.63	1.09	0.6038
	SH	9	0.59	0.63	-0.73	0.41	0.68	1.00	1.32

Figure 1

a

b

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6