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Impact of defect configuration on the clinical outcome following surgical regenerative therapy of peri-implantitis

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Abstract

Objectives: The present study aimed at investigating the impact of defect configuration on the clinical outcome of surgical regenerative therapy of peri-implantitis lesions using a natural bone mineral in combination with a collagen membrane (NBM+CM).

Materials and Methods: Twenty-seven patients ($n = 27$ defects) exhibited three different types of peri-implantitis lesions including either Class Ib (buccal dehiscence+semicircumferential), Class Ic (buccal dehiscence+circumferential), or Class Ie (circumferential) intra-bony defects ($n = 9$ defects per group). All defects were treated with access flap surgery and the application of NBM+CM.

Results: At 6 and 12 months, Class Ie defects tended to reveal higher changes in the mean probing depth (PD) and clinical attachment level (CAL) values when compared with Class Ib and Class Ic groups. However, significant differences were only observed at 6 months (PD: 2.9 ± 0.3 *versus* 1.4 ± 0.5 *versus* 1.3 ± 0.7 mm; CAL: 2.5 ± 0.5 *versus* 0.9 ± 0.8 *versus* 0.9 ± 0.7 mm). Site-level analysis has pointed to lowest PD and CAL changes at the midbuccal aspect of Class Ib and Class Ic groups.

Conclusion: Defect configuration may have an impact on the clinical outcome following surgical regenerative therapy of peri-implantitis lesions. While Class Ie defects seem to be promising in conjunction with NBM+CM, Class Ib and Class Ic may be considered as unfavourable.

Key words: bone graft; collagen membrane; defect configuration; peri-implantitis; surgical regenerative therapy

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Previous results from controlled clinical studies have pointed out that non-surgical treatment of peri-implantitis appears to be unpredictable and potential beneficial clinical outcomes may be limited to a period of 6–12 months (Schwarz et al. 2005, 2006a, d, Renvert et al. 2006, 2008, 2009a). This strong tendency towards a re-infection of the peri-implant pocket may primarily be explained by the limited efficacy of a non-surgical surface debridement procedure to completely remove bacterial contaminants from exposed structured titanium implant surfaces, thus impeding the establishment of a new bone-to-implant contact (BIC) (Schwarz et al. 2006c). In contrast, surgical treatment of peri-implantitis lesions using open flap debridement and a submerged healing procedure was proven to be more effective in promoting bone regeneration and BIC in animals (Schwarz et al. 2006c, Renvert et al. 2009b). Consequently, numerous experimental studies have focused on the potential improvement of surgical protocols including implant surface debridement and decontamination as well as a combination with bone augmentation procedures and the principle of guided bone regeneration (GBR) (Claffey et al. 2008). Limited clinical data suggest that the clinical outcome obtained following surgical regenerative therapy of peri-implantitis appears to be more predictable than any

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type of non-surgical treatment approach (Schwarz et al. 2006b, 2008, 2009, Roos-Jansåker et al. 2007b). In particular, previous studies and case series using various types of bone graft substitutes, with or without the application of a barrier membrane, reported on clinical and radiological improvements over a period of 6–12 months (Schwarz et al. 2006b, Roos-Jansåker et al. 2007b). However, the long-term stability of these promising results appeared to be mainly influenced by the physicochemical properties of the applied bone graft substitute. While the application of a natural bone mineral (NBM) in combination with a native collagen membrane (CM) resulted in clinical improvements over a period of 4 years, the long-term outcome obtained with a nanocrystalline hydroxyapatite (NHA) was considered as poor (Schwarz et al. 2008, 2009). From a biological point of view, however, one should keep in mind that the outcome of a surgical regenerative treatment approach might also be influenced by the defect configuration of the peri-implantitis lesion. In particular, it has been reported that both naturally occurring human- and ligature-induced peri-implantitis lesions in animals most commonly featured a combined defect configuration including a supracrestal (Class II) (humans: 79%; dogs: 53.3%) as well as an intra-bony aspect. The latter could be differentiated into five characteristic defect Classes (Ia–e) (Schwarz et al. 2007). In particular, human defects most frequently (55.3%) exhibited a circular bone resorption under maintenance of the buccal and oral compacta (i.e. Class Ie). This was followed by buccal dehiscence defects revealing a semicircular bone resorption to the middle of the implant body (i.e. Class Ib; 15.8%), and buccal dehiscence defects with a circular bone resorption under either maintenance (i.e. Class Ic; 13.3%) or loss (i.e. Class Id; 10.2%) of the lingual compacta. The lowest frequency featured conventional buccal dehiscence defects (i.e. Class Ia; 5.4%) (Schwarz et al. 2007). While surgical regenerative treatment of larger Class II components may be challenging, this approach seems to be particularly suitable for Class I defects. Unfortunately, previous experimental and clinical studies merely provide insufficient or even no details on the specific defect configuration of the treated defects (Claffey et al. 2008). So far, only one controlled clinical case series clearly defined Class Ie defects exhibiting a minor Class II component as an inclusion criterion during patient selection (Schwarz et al. 2006b). However, this inclusion criterion was mainly related to the high frequency of Class Ie defects, thus facilitating patient recruitment. So far, however, the potential influence of different Class I defect configurations on the outcome of surgical regenerative therapy of peri-implantitis lesions still remains unknown. Therefore, the aim of this prospective clinical study was to investigate and compare clinical parameters following surgical regenerative therapy of Class Ib, Class Ic, and Class Ie defects using NBM+CM over a period of 12 months.

Materials and Methods

Study population

For this prospective, parallel-design study, 27 partially edentulous patients suffering from moderate to advanced peri-implantitis (Mombelli & Lang 1994) were included. They were selected from a total of 38 subjects who attended the Department of Oral Surgery, Heinrich Heine University, Düsseldorf, Germany. Each patient was given a detailed description of the procedure and was required to sign an informed consent before participation. The study was in accordance with the Helsinki Declaration of 1975, as revised in 2000, and all participants signed informed consent forms. The study protocol was approved by the ethics committee of the Heinrich Heine University.

Patient selection

The patient population consisted of three men and 24 women (mean age 48.5 ± 14.6 years) exhibiting one implant each (total $n = 27$ implants). For patient selection, the following inclusion criteria were defined: (1) presence of at least one screw-type titanium implant exhibiting either a Class Ib (i.e. buccal dehiscence+semicircular bone resorption to the middle of the implant body), Class Ic (i.e. buccal dehiscence+circular bone resorption under maintenance of the lingual compacta), or Class Ie (i.e. circular bone resorption under maintenance of the buccal and oral compacta) defect configuration (Fig. 1) with a probing depth (PD) of >6 mm and an intra-bony component of >3 mm as detected clinically (i.e. bone sounding) and radiologically, (2) Class II $\leqslant 1$ mm, (3) no implant mobility, (4) single tooth and bridgework restaurations without overhangings or margins, (5) no evidence of occlusal overload, (6) presence of keratinized peri-implant mucosa to facilitate a repositioning of the mucoperiosteal flap at the augmented areas, (7) treated chronic periodontitis and proper periodontal maintenance care, (8) a good level of oral hygiene [plaque index (PI) <1; Löe 1967], (9) no systemic diseases that could influence the outcome of the therapy [i.e. diabetes (HbA1c <7), osteoporosis, bisphosphonate medication], and (10) non-smoker or light smoking status in smokers (<10 cigarettes per day). Hollow cylinder implants were excluded from the study. The distribution, mean age, and position of the included implant systems in different groups (i.e. Class Ib, Class Ic, and Class Ie) are presented in Tables 1 and 2 (Fig. 2).

Initial course of non-surgical treatment

In order to reduce the acute signs of inflammation, all patients received a single course of non-surgical instrumentation of respective titanium implants at

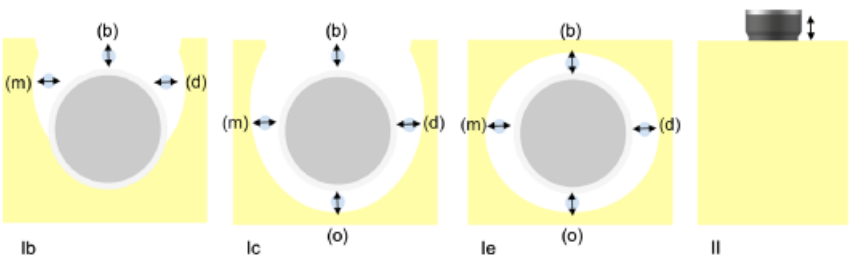

Fig. 1. Intra-operative assessment of the defect components. Class Ib (i.e. buccal dehiscence +semicircular bone resorption to the middle of the implant body). Class Ic (i.e. buccal dehiscence+circular bone resorption under maintenance of the lingual compacta). Class Ie (i.e. circular bone resorption under maintenance of the buccal and oral compacta); intra-bony component (i), blue circles; circumferential (i.e. width) component s(c), arrows. Class II: supraalveolar component s(a), arrow. m, mesial aspect; d, distal aspect; b, buccal aspect; o, oral aspect.

Table 1. Distribution and mean age (years ± SD) of different implant systems in both groups at baseline

Group	BRA	CAM	ITI	TSV	Age
Class Ib ($n = 9$)	–	2	4	3	4.8 ± 2.1
Class Ic ($n = 9$)	1	2	3	3	3.8 ± 1.2
Class Ie ($n = 9$)	–	4	3	2	4.2 ± 0.6

BRA, Brånemark System® (cylindrical screw, machined surface; Nobel Biocare, Göteborg, Sweden); CAM, Camlog Screw Line® (cylindrical screw, sand-blasted, and acid-etched surface; Camlog Biotechnologies AG, Basel, Switzerland); ITI, ITI®, Institut Straumann AG (cylindrical screw, sand-blasted large grit, and acid-etched surface); TSV, Tapered Screw Vent® (tapered screw, grit-blasted surface; Zimmer Dental, Freiburg, Germany).

Table 2. Position and baseline defect characteristics in mm (mean ± SD)

Group	Upper jaw		Lower jaw		s(a)	s(c)	i
	anterior	posterior	anterior	posterior			
Class Ib ($n = 9$)	0	2	0	7	0.8 ± 0.4	2.2 ± 0.5	3.9 ± 0.4
Class Ic ($n = 9$)	1	4	0	4	0.8 ± 0.5	2.3 ± 0.5	4.1 ± 0.6
Class Ie ($n = 9$)	2	2	0	5	0.6 ± 0.5	2.2 ± 0.6	4.2 ± 0.7

Comparisons between groups (one-way ANOVA): $p > 0.001$; respectively.
s(a), supraalveolar component; s(c), circumferential component (i.e. width); i, intra-bony component.

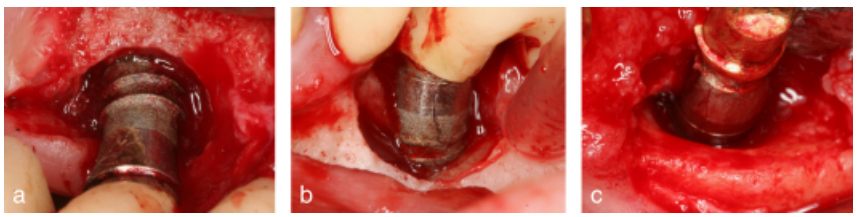

Fig. 2. Intra-operative views following granulation tissue removal, implant surface debridement (carbon curets), and decontamination (cotton pellet soaked in sterile saline). (a) Class Ib+Class II (1 mm). (b) Class Ic. (c) Class Ie.

4 weeks before the start of the experimental part of the study. For this procedure, an Er:YAG laser device using a specially designed cone-shaped glass fibre tip emitting a radial and axial laser beam was used. Laser parameters were set at 100 mJ/pulse (12.7 J/cm^2), 10 Hz, and pulse energy at the tip was approximately 85 mJ/pulse (Schwarz et al. 2003, 2005, 2006d). The fibre tip was guided under copious water irrigation in a semicircular motion from coronal to apical parallel to the implant surface in contact mode.

Clinical measurements

The following clinical measurements were performed immediately before surgery (baseline), as well as at 6 and 12 months after treatment using a periodontal probe (PCP 12, Hu-Friedy, Leimen, Germany): (1) PI (Löe 1967), (2) bleeding on probing (BOP), evaluated as present if bleeding was evident within 30 s after probing, or absent, if no bleeding was noticed within 30 s after probing, (3) PD measured from the mucosal margin to the bottom of the probeable pocket, (4) mucosal recession (MR) measured from the implant neck (IN) to the mucosal margin, and (5) clinical attachment level (CAL) measured from IN to the bottom of the probeable pocket. PD, MR, and CAL scores were recorded to the nearest millimetre. The primary outcome variable was CAL. All measurements were made at six aspects per implant, mesiobuccal (mb), midbuccal (b), distobuccal (db), mesiooral (mo), midoral (o), and distooral (do), by one blinded and previously calibrated investigator. Wherever applicable (Group Ib: eight patients; Group Ic: seven patients: Group Ie: eight patients), the implant-supported suprastructures were removed for all clinical measurements.

Configuration assessment of peri-implant bone defects

During open flap surgery, the supraalveolar, circumferential, and intra-bony components of the defects were measured by one blinded and previously calibrated investigator (Fig. 1).

1. supraalveolar component – s(a) of the defect, measured as linear mesial or distal distance from the borderline between the bony and the transmucosal part (BTB) of the implant to the coronal extension of the adjacent alveolar bone (AC),
2. circumferential component (i.e. width) – s(c) of the defect, measured as the linear distance from the vestibular – s(c-v), mesial – s(c-m), distal – s(c-d), and oral – s(c-o) bone wall of the defect to the implant surface, and
3. intra-bony component (i) of the defect, measured as the linear distance from AC to the bottom of the defect (v, m, d, o; respectively).

The baseline defect characteristics in both groups are presented in Table 2.

Intra-examiner reproducibility

Five patients, each showing two implants with PDs ⩾ 4 mm on at least one aspect, were used to calibrate the examiner. The examiner evaluated (i.e. PD, MR, and CAL values) the patients on two separate occasions, 48 h apart. Calibration was accepted if measurements at baseline and at 48 h were within a millimetre at > 90% of the time.

Surgical regenerative treatment

Under local anaesthesia, full-thickness mucoperiosteal flaps were raised vestibularly and orally by means of intracrevicular incisions. Subsequently, all granulation tissue was completely removed from the defect area and the implant surfaces were thoroughly debrided using carbon curettes (Straumann® Dental Implant System, Straumann AG, Basel, Switzerland). Following cleaning, implant surface decontamination was accomplished using cotton pellets soaked in sterile saline. NBM (Geistlich BioOss® spon-

giosa granules, particle size 0.25–1 mm, Geistlich Biomaterials, Wolhusen, Switzerland) was applied in a way as to homogeneously fill the intra-bony defect component. Before its application, the graft material was moistened in sterile saline for 5 min. Following grafting, a bioabsorbable type I/III CM of porcine origin (Geistlich BioGide®, Geistlich Biomaterials) was size adapted in a way as to cover the entire defect including 2–3 mm of the surrounding alveolar bone. For membrane fixation or stabilization, neither sutures nor pins were used. To ensure a non-submerged healing, the mucoperiosteal flaps were repositioned coronally and fixed with vertical or horizontal mattress sutures. All treatments were performed by the same experienced surgeon (F. S.).

Postoperative care and maintenance

Postoperative care consisted of rinsing with a 0.2% chlorhexidine digluconate solution (Corsodyl®, GlaxoSmithKline Consumer Healthcare, Bühl, Germany) twice a day for 2 weeks. The sutures were removed 10 days after the surgery. Recall appointments were scheduled every second week during the first 2 months after surgery and monthly during the short-term observation period of 6 months. During the rest of the study period, the patients were recalled every 3 months. A supragingival professional implant/tooth cleaning and reinforcement of oral hygiene was provided at 1, 3, 6, 9, and 12 months after treatment (K. S. and N. S.).

Statistical analysis

The statistical analysis was performed using a commercially available software program (PASW Statistics 18.0, SPSS Inc., Chicago, IL, USA). Mean values and standard deviations were calculated for each variable and group. The data rows were examined using the Kolmogorow–Smirnow test for normal distribution. Analysis of variance (one-way ANOVA) and post hoc testing with Bonferroni's correction was used for between-group comparisons of the changes in the mean values from baseline to 6 and 12 months, respectively. To allow for multiple comparisons, the level of significance was set at $p < 0.001$.

Power calculation

For the power analysis, a standard normal distribution was assumed. The probability of a type I error was set at 0.001. Sigma (0.75) was estimated based on the standard deviations observed in previous studies (Schwarz et al. 2006b, 2008). Defining CAL as the primary outcome variable, a clinically relevant difference was set at 1 mm. For the given sample size of nine patients per group, a 73% power detecting a 1 mm difference in CAL was calculated (Power and Precision, Biostat, Englewood, NJ, USA).

Results

In all groups, the postoperative healing was considered as generally uneventful. No complications such as allergic reactions, swellings, abscesses, or infections were observed throughout the entire study period. All groups commonly revealed a slight exposure of CM at the transmucosal aspect of the wound area. The exposed CM underwent a fast degradation, resulting in an almost complete soft tissue coverage after 8–10 days of healing.

The mean PI and BOP values as assessed in different groups at baseline and after 6 and 12 months are summarized in Table 3. These values did not reveal a statistically significant difference between the groups at baseline ($p > 0.001$; respectively). All experimental sites exhibited only minor changes in the mean PI values throughout the entire study period without showing any significant differences between groups ($p > 0.001$; respectively). The mean BOP values were markedly reduced in all groups after 6 and 12 months of healing. At 12 weeks, Class Ie defects revealed significantly higher mean BOP reductions when compared with Class Ic ($p < 0.001$) defects. Even though the mean BOP reductions also tended to be lower in comparison with Class Ib defects at 6 and 12 months, these values did not reach statistical significance ($p > 0.001$; respectively) (Table 3).

The mean PD, MR, and CAL values in different groups at baseline and after 6 and 12 months are summarized in Table 3. These values did not reveal a statistically significant difference between the groups at baseline ($p > 0.001$; respectively). All groups exhibited a marked reduction in the mean PD and CAL values at both 6 and 12 months after therapy. In particular, Class Ib defects showed a mean PD reduction of 1.4 ± 0.5 and 1.6 ± 0.9 mm and a mean CAL gain of 0.9 ± 0.8 and 1.2 ± 1.1 mm at 6 and 12 months, respectively. Similarly, Class Ic defects showed a mean PD reduction of 1.3 ± 0.7 and 1.6 ± 0.7 mm and a mean CAL gain of 0.9 ± 0.7 and 1.1 ± 0.9 mm at 6 and 12 months, respectively. Between-group comparisons of the differences in the mean PD and CAL values

Table 3. Clinical parameters (mean ± SD) at baseline, 6 and 12 months in different groups ($n = 27$ patients)

	Baseline	6 months	Difference	12 months	Difference
Plaque index					
Class Ib	0.7 ± 0.3	0.6 ± 0.5	0.1 ± 0.3	0.8 ± 0.4	0.1 ± 0.4
Class Ic	0.5 ± 0.4	0.7 ± 0.5	0.2 ± 0.4	0.6 ± 0.5	0.1 ± 0.3
Class Ie	0.9 ± 0.4	0.8 ± 0.6	-0.1 ± 0.3	0.7 ± 0.6	-0.2 ± 0.3
Bleeding on probing (%)					
Class Ib	81.5 ± 17.6	46.3 ± 13.9	35.2 ± 15.5	42.6 ± 14.7	38.9 ± 16.6
Class Ic	83.3 ± 14.4	53.7 ± 7.3	29.6 ± 11.1	57.4 ± 8.7	25.9 ± 14.7*
Class Ie	85.2 ± 13.0	27.8 ± 11.8	57.4 ± 18.8	24.1 ± 8.8	61.1 ± 16.7
Probing depth (mm)					
Class Ib	6.7 ± 0.7	5.3 ± 0.5	1.4 ± 0.5*	5.1 ± 0.6	1.6 ± 0.9
Class Ic	7.1 ± 0.6	5.8 ± 0.7	1.3 ± 0.7*	5.5 ± 0.5	1.6 ± 0.7
Class Ie	7.0 ± 0.5	4.1 ± 0.3	2.9 ± 0.3	4.3 ± 0.5	2.7 ± 0.7
Mucosal recession (mm)					
Class Ib	0.4 ± 0.5	0.9 ± 0.3	0.5 ± 0.5	0.8 ± 0.4	0.4 ± 0.7
Class Ic	0.4 ± 0.5	0.8 ± 0.4	0.4 ± 0.5	0.9 ± 0.6	0.5 ± 0.5
Class Ie	0.5 ± 0.5	0.9 ± 0.3	0.4 ± 0.5	0.8 ± 0.4	0.3 ± 0.6
Clinical attachment level (mm)					
Class Ib	7.1 ± 0.9	6.2 ± 0.6	0.9 ± 0.8*	5.9 ± 0.8	1.2 ± 1.1
Class Ic	7.5 ± 0.9	6.6 ± 0.9	0.9 ± 0.7*	6.4 ± 0.9	1.1 ± 0.9
Class Ie	7.5 ± 0.8	5.0 ± 0.5	2.5 ± 0.5	5.1 ± 0.6	2.4 ± 1.0

Between-group comparisons of the changes in the mean values from baseline to 6 and 12 months of healing (one-way ANOVA):
*Compared with Class Ie, $p < 0.001$.

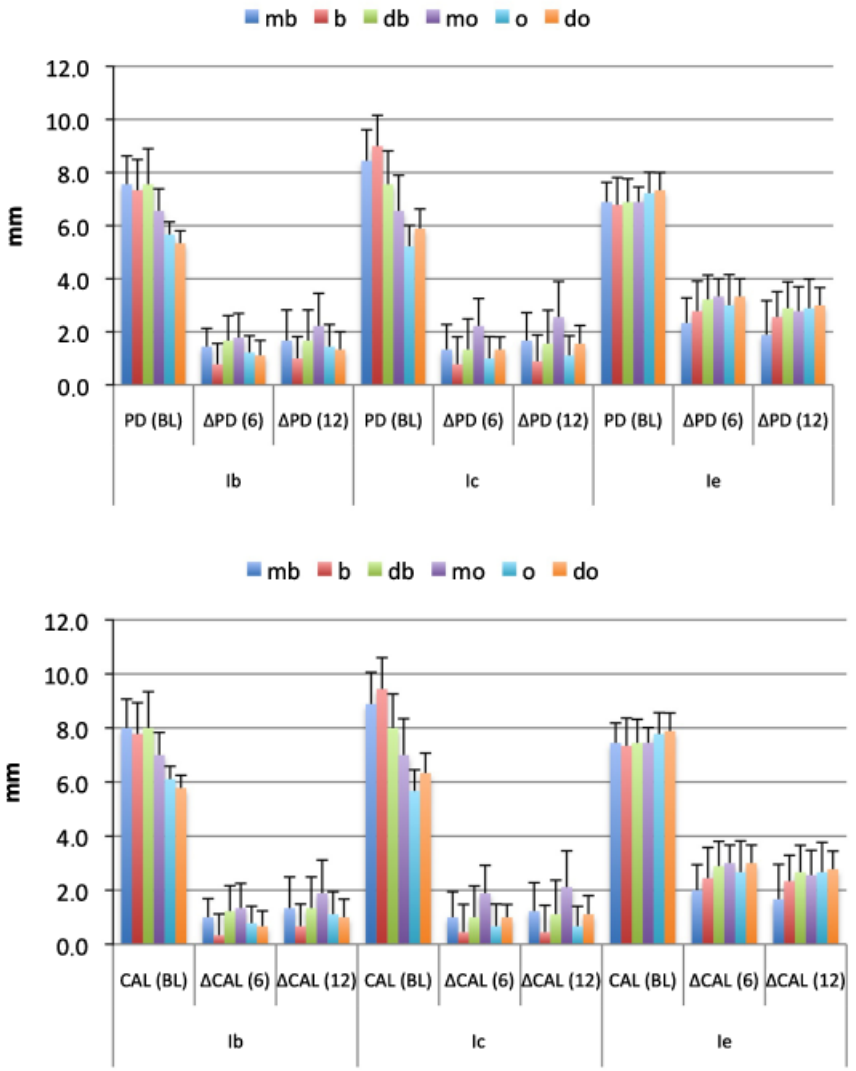

Fig. 3. Site-level analysis of the mean probing depth (PD) and clinical attachment level (CAL) values (± standard deviation) at baseline (BL) and the changes (Δ) in the mean values from BL to 6 and 12 months in different groups at six aspects: mesiobuccal (mb), midbuccal (b), distobuccal (db), mesiooral (mo), midoral (o), and distooral (do) ($n = 27$ implants). (a) PD (mm). (b) CAL (mm).

Table 4. Frequency distribution of CAL gain after 12 months in different groups ($n = 27$ patients)

CAL gain (mm)	Class Ib		Class Ic		Class Ie	
	No.	%	No.	%	No.	%
0	3	33.3	3	33.3	0	0.0
1	2	22.2	2	22.2	2	22.2
2	3	33.3	4	44.4	2	22.2
3	1	11.1	0	0.0	4	44.4
4	0	0.0	0	0.0	1	11.1

CAL, clinical attachment level.

measured at either 6 or 12 months were statistically not significant ($p > 0.001$; respectively). Class Ie defects showed a pronounced mean PD reduction of 2.9 ± 0.3 and 2.7 ± 0.7 mm and a mean CAL gain of 2.5 ± 0.5 and 2.4 ± 1.0 mm at 6 and 12 months, respectively. At 6 months, changes in the mean PD and CAL values were significantly higher at Class Ie defects when compared with either Class Ib ($p < 0.001$, $p < 0.001$; respectively) or Class Ic ($p < 0.001$, $p < 0.001$; respectively) defects (Table 3). Even though Class Ie defects also tended to reveal higher mean PD reductions and CAL gains after 12 months of healing, the differences to Class Ib and Class Ic groups did not reach statistical significance ($p > 0.001$; respectively).

A site-level analysis of the mean PD and CAL values at baseline and the changes in the mean values at 6 and 12 months in different groups is presented in Fig. 3a and b. Basically, the analysis of the baseline values at Class Ie defects revealed comparable mean PD and CAL scores at all six aspects investigated. In contrast, Class Ib and Class Ic defects were characterized by increased PD and CAL values at the buccal (i.e. mb, b, db) as well as decreased values at the corresponding lingual (i.e. mo, o, do) aspects. After 6 and 12 months of healing, changes in the mean PD and CAL values appeared to be comparable at all buccal and lingual aspects of Class Ie defects. In contrast, Class Ib and Class Ic defects commonly featured lower mean PD reductions and CAL gains at all aspects investigated. However, in both groups, the site-level analysis revealed the lowest changes in the mean PD and CAL values at the b aspect of the treated implants (Fig. 3).

The frequency distribution of CAL gains after 12 months in different groups is shown in Table 4. In particular, at Class Ib defects, the majority of the sites revealed a CAL gain of 1 mm (22.2%) and 2 mm (33.3%). A CAL gain of 3 mm was observed at only one site (11.1%). Similarly, Class Ic defects were only characterized by a CAL gain of 1 mm (22.2%) and 2 mm (44.4%). In contrast, at Class Ie defects, a CAL gain of either 1 or 2 mm was observed in 22.2% and 22.2% of the sites, respectively. While a CAL gain of 3 mm was observed at four sites (44.4%), one defect even revealed a CAL gain of 4 mm (11.1%) (Table 4).

Discussion

The present study attempted to evaluate the impact of defect configuration on the clinical outcome of surgical regenerative therapy of moderate to advanced peri-implantitis defects using NBM+CM.

Within the limitations, the present data have indicated that Class Ie defects exhibited significantly higher improvements of mean BOP (12 months) as well as PD and CAL (6 months, respectively) values when compared with either Class Ib (PD and CAL) or Class Ic (BOP, PD, and CAL) groups. When interpreting the present results, it was also observed that the major improvements in the mean BOP, PD, and CAL values occurred after 6 months of healing. At 12 months, the mean PD and CAL values remained

stable in all groups. However, a slight increase in the mean BOP scores was noted for Class Ic defects, which in turn might point to a tendency towards recurrence in this group. In this context, it is important to emphasize that the application of NBM+CM at Class Ie defects resulted in stable clinical improvements over a period of 4 years (Schwarz et al. 2009). Accordingly, the assessment of the long-term stability of the clinical parameters obtained in Class Ib and Class Ic groups may be essential in order to clarify this issue.

The clinical outcomes as noted for Class Ie defects after 6 and 12 months are in accordance with the results of a previous case series comparing NBM+CM to NHA for the surgical regenerative treatment of peri-implantitis lesions (Schwarz et al. 2006b, 2008). In particular, NBM+CM-treated defects revealed a decrease of the mean BOP scores from 78% at baseline to 28% and 29% at 6 and 12 months, respectively. The mean PD scores also decreased from 7.1 ± 0.8 mm at baseline to 4.5 ± 0.7 and 4.4 ± 0.6 mm at 6 and 12 months, respectively. Similarly, the mean CAL scores decreased from 7.5 ± 1.0 mm at baseline to 5.2 ± 0.8 and 5.1 ± 0.7 mm at 6 and 12 months, respectively (Schwarz et al. 2006b, 2008). This study only included Class Ie defects exhibiting either a circular or a semicircular configuration of comparable sizes (i.e. intra-bony, horizontal, supraalveolar components) as noted for the present Class Ie defects. Unfortunately, previous clinical studies or case series aimed at investigating various types of surgical regenerative therapy of peri-implantitis lesions did not report on the specific morphological and dimensional characteristics of the included defects (Behneke et al. 2000, Khoury & Buchmann 2001, Roos-Jansåker et al. 2007a, b). Accordingly, these are the first clinical data explicitly reporting on the clinical outcome of a regenerative approach at either Class Ib or Class Ic defects. Keeping in mind the poor clinical outcome in comparison with the Class Ie group, both types of defect classes might be considered to provide a less favourable biological environment for the application of NBM+CM. In this context, it is important to emphasize that previous animal studies have pointed to the potential of NBM+CM to support a certain amount of new bone formation and subsequently re-osseointegration at ligature-induced peri-implantitis defects (Nociti et al. 2000, 2001a, b). In these studies, an air powder flow was used for the decontamination of acid-etched rough titanium implants, which were, subsequent to the GBR procedure, left to heal in a submerged position for 5 months. However, the histomorphometric evaluation revealed no significant differences with respect to bone formation and re-osseointegration at sites receiving either surface debridement alone (49.5%/26.8%), CM alone (51%/26.6%), NBM alone (55.7%/28%), or a combination of NBM+CM (48%/25.6%) (Nociti et al. 2000). Even though the authors also did not report on the specific defect characteristics, one might speculate that these ligature-induced sites were predominantly of a Class Ie nature (Schwarz et al. 2007). These limited histological data may indicate that the application of NBM is, to a certain extent, also associated with an obstruction of the former defect area by residual bone graft particles. Considering the specific morphological and dimensional characteristics of all three groups investigated, one might hypothesize that an NBM-mediated obstruction of the former defect area seems to be more likely at Class Ie than at either Class Ib or Class Ic sites. This assumption might be supported by the clinical observation that Class Ib and Class Ic groups revealed the lowest PD and CAL improvements at the b aspect of the defect area. However, an experimental study aimed at investigating the impact of defect configuration on the histological outcome of healing at peri-implantitis sites following application of NBM+CM is required in order to clarify this issue.

In conclusion, the present study has pointed to a potential impact of the defect configuration on the clinical outcome following surgical regenerative therapy of peri-implantitis lesions. While Class Ie defects seem to be promising in conjunction with NBM+CM, Class Ib and Class Ic must be considered as unfavourable. From both a clinical and a scientific point of view, future studies aimed at investigating any type of surgical treatment of peri-implantitis are encouraged to properly report on the specific configuration of the included defects.

References

Behneke, A., Behneke, N. & d'Hoedt, B. (2000) Treatment of peri-implantitis defects with autogenous bone grafts: six-month to 3-year results of a prospective study in 17 patients. *International Journal of Oral and Maxillofacial Implants* **15**, 125–138.

Claffey, N., Clarke, E., Polyzois, I. & Renvert, S. (2008) Surgical treatment of peri-implantitis. *Journal of Clinical Periodontology* **35**, 316–332.

Khoury, F. & Buchmann, R. (2001) Surgical therapy of peri-implant disease: a 3-year follow-up study of cases treated with 3 different techniques of bone regeneration. *Journal of Periodontology* **72**, 1498–1508.

Löe, H. (1967) The gingival index, the plaque index and the retention index systems. *Journal of Periodontology* **38** (Suppl.), 610–616.

Mombelli, A. & Lang, N. P. (1994) Clinical parameters for the evaluation of dental implants. *Periodontology 2000* **4**, 81–86.

Nociti, F. H. Jr., Caffesse, R. G., Sallum, E. A., Machado, M. A., Stefani, C. M. & Sallum, A. W. (2000) Evaluation of guided bone regeneration and/or bone grafts in the treatment of ligature-induced peri-implantitis defects: a morphometric study in dogs. *Journal of Oral Implantology* **26**, 244–249.

Nociti, F. H. Jr., Machado, M. A., Stefani, C. M. & Sallum, E. A. (2001a) Absorbable versus nonabsorbable membranes and bone grafts in the treatment of ligature-induced peri-implantitis defects in dogs: a histometric investigation. *International Journal of Oral and Maxillofacial Implants* **16**, 646–652.

Nociti, F. H. Jr., Machado, M. A., Stefani, C. M., Sallum, E. A. & Sallum, A. W. (2001b) Absorbable versus nonabsorbable membranes and bone grafts in the treatment of ligature-induced peri-implantitis defects in dogs. Part I. A clinical investigation. *Clinical Oral Implants Research* **12**, 115–120.

Renvert, S., Lessem, J., Dahlen, G., Lindahl, C. & Svensson, M. (2006) Topical minocycline microspheres versus topical chlorhexidine gel as an adjunct to mechanical debridement of incipient peri-implant infections: a randomized clinical trial. *Journal of Clinical Periodontology* **33**, 362–369.

Renvert, S., Lessem, J., Dahlen, G., Renvert, H. & Lindahl, C. (2008) Mechanical and repeated antimicrobial therapy using a local drug delivery system in the treatment of peri-implantitis: a randomized clinical trial. *Journal of Periodontology* **79**, 836–844.

Renvert, S., Polyzois, I. & Maguire, R. (2009b) Re-osseointegration on previously contaminated surfaces: a systematic review. *Clinical Oral Implants Research* **20** (Suppl. 4), 216–227.

Renvert, S., Samuelsson, E., Lindahl, C. & Persson, G. R. (2009a) Mechanical non-surgical treatment of peri-implantitis: a double-blind randomized longitudinal clinical study. I: clinical results. *Journal of Clinical Periodontology* **36**, 604–609.

Roos-Jansåker, A. M., Renvert, H., Lindahl, C. & Renvert, S. (2007a) Submerged healing following surgical treatment of peri-implantitis: a case series. *Journal of Clinical Periodontology* **34**, 723–727.

Roos-Jansåker, A. M., Renvert, H., Lindahl, C. & Renvert, S. (2007b) Surgical treatment of

peri-implantitis using a bone substitute with or without a resorbable membrane: a prospective cohort study. *Journal of Clinical Periodontology* **34**, 625–632.

Schwarz, F., Bieling, K., Bonsmann, M., Latz, T. & Becker, J. (2006d) Nonsurgical treatment of moderate and advanced periimplantitis lesions: a controlled clinical study. *Clinical Oral Investigations* **10**, 279–288.

Schwarz, F., Bieling, K., Latz, T., Nuesry, E. & Becker, J. (2006b) Healing of intrabony peri-implantitis defects following application of a nanocrystalline hydroxyapatite (Ostim) or a bovine-derived xenograft (Bio-Oss) in combination with a collagen membrane (Bio-Gide). A case series. *Journal of Clinical Periodontology* **33**, 491–499.

Schwarz, F., Bieling, K., Nuesry, E., Sculean, A. & Becker, J. (2006a) Clinical and histological healing pattern of peri-implantitis lesions following non-surgical treatment with an Er:YAG laser. *Lasers in Surgery and Medicine* **38**, 663–671.

Schwarz, F., Herten, M., Sager, M., Bieling, K., Sculean, A. & Becker, J. (2007) Comparison of naturally occurring and ligature-induced peri-implantitis bone defects in humans and dogs. *Clinical Oral Implants Research* **18**, 161–170.

Schwarz, F., Jepsen, S., Herten, M., Sager, M., Rothamel, D. & Becker, J. (2006c) Influence of different treatment approaches on non-submerged and submerged healing of ligature induced peri-implantitis lesions: an experimental study in dogs. *Journal of Clinical Periodontology* **33**, 584–595.

Schwarz, F., Rothamel, D., Sculean, A., Georg, T., Scherbaum, W. & Becker, J. (2003) Effects of an Er:YAG laser and the Vector ultrasonic system on the biocompatibility of titanium implants in cultures of human osteoblast-like cells. *Clinical Oral Implants Research* **14**, 784–792.

Schwarz, F., Sahm, N., Bieling, K. & Becker, J. (2009) Surgical regenerative treatment of peri-implantitis lesions using a nanocrystalline hydroxyapatite or a natural bone mineral in combination with a collagen membrane: a four-year clinical follow-up report. *Journal of Clinical Periodontology* **36**, 807–814.

Schwarz, F., Sculean, A., Bieling, K., Ferrari, D., Rothamel, D. & Becker, J. (2008) Two-year clinical results following treatment of peri-implantitis lesions using a nanocrystalline hydroxyapatite or a natural bone mineral in combination with a collagen membrane. *Journal of Clinical Periodontology* **35**, 80–87.

Schwarz, F., Sculean, A., Rothamel, D., Schwenzer, K., Georg, T. & Becker, J. (2005) Clinical evaluation of an Er:YAG laser for nonsurgical treatment of peri-implantitis: a pilot study. *Clinical Oral Implants Research* **16**, 44–52.

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Clinical Relevance

Scientific rationale for the study: Defect configuration might have a significant impact on the clinical outcome of surgical regenerative therapy of peri-implantitis lesions. This issue, however, has not been addressed in previous studies.

Principal findings: The present results have indicated that at 6 and 12 months after surgery, the application of a NBM+CM at Class Ie defects was associated with higher improvements in the mean PD and CAL values than at either Class Ib or Class Ic defects.

Practical implications: Defect configuration might be considered as a clinical parameter potentially influencing the outcome following surgical regenerative therapy of peri-implantitis lesions using NBM+CM.