Clin Oral Invest (2013) 17:1573–1583
DOI 10.1007/s00784-012-0838-6

ORIGINAL ARTICLE

Early postoperative healing following buccal *single flap approach* to access intraosseous periodontal defects

Roberto Farina · Anna Simonelli · Alessandro Rizzi · Mattia Pramstraller · Alessandro Cucchi · Leonardo Trombelli

Received: 14 March 2012 / Accepted: 31 August 2012 / Published online: 9 September 2012

Abstract
Aim This study aims to evaluate the early postoperative healing of papillary incision wounds and its association with (1) patient/site-related factors and technical (surgical) aspects as well as with (2) 6-month clinical outcomes following buccal single flap approach (SFA) in the treatment of intraosseous periodontal defects.
Methods Forty-three intraosseous defects in 35 patients were accessed with a buccal SFA alone or in combination with a reconstructive technology (graft, enamel matrix derivative (EMD), graft + EMD, or graft + membrane). Postoperative healing was evaluated at 2 weeks using the Early Wound-Healing Index (EHI).
Results EHI ranged from score 1 (i.e., complete flap closure and optimal healing) to score 4 (i.e., loss of primary closure and partial tissue necrosis). SFA resulted in a complete wound closure at 2 weeks in the great majority of sites. A significantly more frequent presence of interdental contact point and interdental soft tissue crater, and narrower base of the interdental papilla were observed at sites with either EHI >1 or EHI=4 compared to sites with EHI = 1. No association between EHI and the 6-month clinical outcomes was observed.
Conclusions At 2 weeks, buccal SFA may result in highly predictable complete flap closure.
Clinical relevance Site-specific characteristics may influence the early postoperative healing of the papillary incision following SFA procedure. Two-week soft tissue healing, however, was not associated with the 6-month clinical outcomes.

Keywords Periodontitis · Alveolar bone loss · Reconstructive surgical procedures · Surgical flaps · Wound healing

R. Farina · A. Simonelli · A. Rizzi · M. Pramstraller · L. Trombelli (✉)
Research Centre for the Study of Periodontal and Peri-Implant Diseases, University of Ferrara,
Corso Giovecca 203,
44100 Ferrara, Italy
e-mail: leonardo.trombelli@unife.it

A. Cucchi
Department of Clinical and Experimental Medicine,
University of Ferrara,
Ferrara, Italy

Introduction

Ideally, during the early phases of healing following the elevation of a gingival flap, flap manipulation should ensure the stabilization of the root surface-adhering blood clot in a biologic environment protected from mechanical and microbiologic challenges. Unfortunately, a dehiscence of the wound margins may occur as a result of a compromised vascular supply due to surgical manipulation and/or tensile forces acting on wound margins. Wound dehiscence may compromise wound stability, which in turn would jeopardize the cascade of biologic events leading to periodontal regeneration [1–4]. Furthermore, when flap surgery is used in association with regenerative technologies, the postoperative loss of primary closure may lead to the partial or complete exfoliation of the implanted graft, contamination of the membrane surface, or premature clearence of the biological agent. In this respect, the significance of primary (unexposed) intention healing as a determinant of periodontal wound healing following regenerative procedures has been universally recognized [5, 6]. In particular, the first postoperative weeks seem to be critical for the maintenance of wound stability [5, 7, 8].

The surgical management of the supracrestal soft tissues, including flap design and suturing technique, seems of paramount importance in controlling the chances of wound failure during the early phases of healing, thus preserving clot stability [9]. Over the years, new surgical techniques specifically designed to optimize functional and esthetic outcomes of reconstructive procedures in the interdental area have been developed and, at least in part, validated. In essence, all the proposed "papilla preservation procedures" approached the main goal of optimizing the primary closure in the interdental area, thus ensuring the central conditions for blood clot stabilization and maturation [10, 11]. Such approaches, either used alone [12–15] or in association with reconstructive devices [12, 13, 15–25], were associated with a variable incidence of preserved primary flap closure within the first postoperative weeks.

Recently, we proposed a minimally invasive surgical procedure, the single flap approach (SFA), designed for reconstructive procedures of intraosseous periodontal defects [26]. The basic principle behind SFA is the unilateral elevation (on the buccal or oral side) of a limited mucoperiosteal flap to allow surgical access depending on the main, buccal, or lingual extension of the intraosseous defect, leaving adjoining gingival tissues intact. Buccal SFA has been shown to be similarly effective to the double flap (i.e., buccal and palatal) approach in supporting clinical improvements as a stand-alone protocol [14] and has been successfully combined with various regenerative technologies, including bone biomaterials with or without provisions for GTR [13, 26, 27]. Preliminary observations revealed that the quality of wound healing in the first postoperative weeks after SFA may substantially differ among patients and sites, ranging from complete flap closure to wound dehiscence due to the complete necrosis of the interproximal tissues [13]. Which factors are implicated in the incidence of early postoperative complications, such as wound dehiscence, following SFA need to be further explored.

The present study was performed to evaluate the early postoperative healing of papillary incision wounds following SFA in the treatment of intraosseous periodontal defects, as assessed by the Early Wound-Healing Index (EHI) [12]. The influence of patient-related and site-specific characteristics as well as technical (surgical) factors on EHI was explored. Also, the association between the EHI and the 6-month clinical outcomes of the procedure was evaluated.

Materials and methods

The study was designed as a single-center clinical trial and conducted at the Research Centre for the Study of Periodontal and Peri-Implant Diseases, University of Ferrara, Italy. All the clinical procedures were performed in accordance with the Declaration of Helsinki and the Good Clinical Practice Guidelines. Each patient provided a written informed consent before participation.

Patient and defect eligibility

Patient were consecutively included in the study if positive for each of the following inclusion criteria: (a) diagnosis of chronic or aggressive periodontitis; (b) no pregnancy or lactation; (c) no systemic diseases that contraindicated periodontal surgery; (d) no use of medications affecting periodontal status; (e) no assumption of anticoagulants, nonsteroidal anti-inflammatory drugs, corticosteroids, or biological agents for the treatment of rheumatoid arthritis (e.g., TNF-α blockers, IL-1 blockers, IL-6 blockers); (f) presence of $\geq$1 deep (probing pocket depth $\geq$5 mm, radiographic depth $\geq$3 mm) interproximal intraosseous periodontal defect; (g) limited to no extension of the defect on the lingual or palatal side as assessed by preoperative bone sounding; and (h) full-mouth plaque score [28] and full-mouth bleeding score <20 % at the time of the surgical procedure.

Third molars, teeth with degree III mobility, furcation involvement, or inadequate endodontic treatment and/or restoration were excluded from the study.

Experimental protocol

Presurgery procedures

Each patient underwent a full-mouth session of scaling and root planing using mechanical and hand instrumentation and received personalized oral hygiene instructions. Temporary splinting and/or occlusal adjustment were performed for teeth with degree I or II mobility at re-evaluation following nonsurgical instrumentation. The surgical phase was delayed until the achievement of minimal residual inflammation at the defect site.

Surgical procedures

All surgeries were performed by one experienced periodontal surgeon (LT) using 2.5 magnifying loops. The site of surgery was anesthetized using mepivacaine-epinephrine 1:100,000. Transcrevicular probing (bone sounding) was always performed presurgery to determine the characteristics of the bony defect, including the defect morphology and extension, the probing bone level, and the horizontal component of bone loss.

The surgical access was performed by the elevation of a buccal mucoperiosteal flap according to previously detailed principles of the SFA (Fig. 1) [13, 14, 26, 27]. Briefly, a buccal envelope flap without vertical releasing incisions was performed. Sulcular incisions were made following the gingival margin of the teeth included in the surgical area. The mesiodistal extension of the flap was kept limited while ensuring access for defect debridement. An oblique or

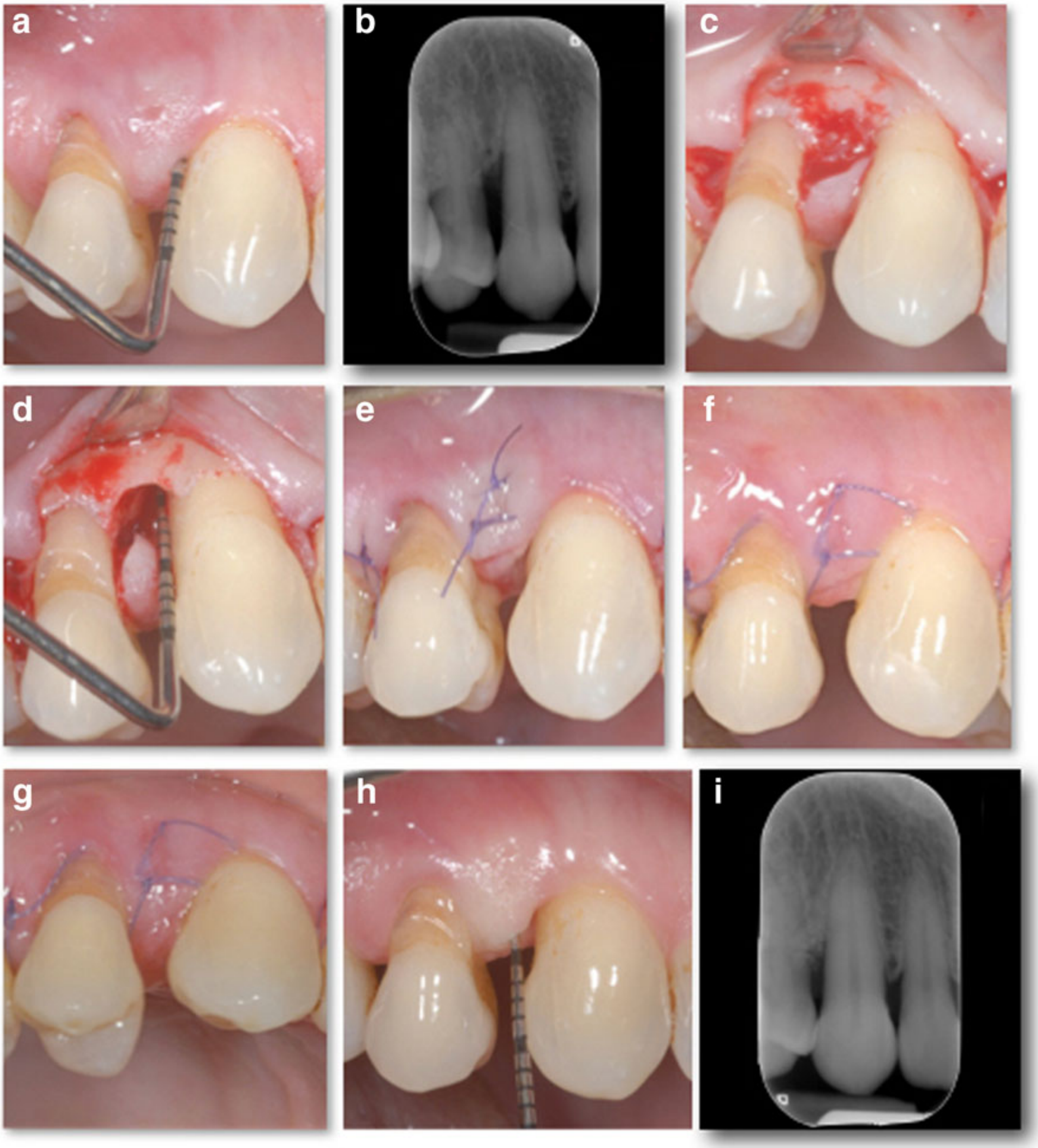

Fig. 1 Surgical access according to the single flap approach [13, 14, 26, 27, 44]. **a** Preoperative clinical attachment loss at the distobuccal aspect of a lateral right maxillary canine. **b** Radiographic aspect at presurgery. **c** Sulcular incisions are made following the gingival margin of the teeth included in the surgical area. An oblique or horizontal butt-joint incision is made at the level of the interdental papilla. **d** The elevation of a buccal mucoperiosteal flap allows for proper root/defect debridement. Note the untouched interdental papilla. **e** Wound closure is obtained with a horizontal internal mattress suture at the base of the papilla, first, and another internal mattress suture (or interrupted suture) at the most coronal portion of the papilla, second. **f** Soft tissue healing at suture removal performed at 2 weeks following surgery. **g** Complete wound closure with absence of fibrin line at the incision margins as observed at 2 weeks after surgery. **h** Clinical aspect at 6 months following surgery. **i** Radiographic aspect at 6 months following surgery

horizontal butt-joint incision was made at the level of the interdental papilla overlying the intraosseous defect; the greater the distance from the tip of the papilla to the underlying bone crest, the more apical (i.e., close to the base of the papilla) the buccal incision in the interdental area. However, the interdental incision was performed at least 1 mm coronal to the underlying bone crest. This provided an adequate amount of pristine supracrestal soft tissue connected to the undetached oral papilla to ensure subsequent flap adaptation and suturing and permitted proper surgical access to the intraosseous defect. For each defect, a microsurgical periosteal elevator (P-TROM periosteal elevator, Hu-Friedy, Milan, Italy) was used to raise a flap only on the buccal side, leaving the oral portion of the interdental supracrestal soft tissues undetached. Root and defect debridement were performed using hand and ultrasonic instruments. At the completion of root and defect instrumentation, defects were left to fill with a blood clot or treated with a reconstructive technology (hydroxyapatite-based graft or enamel matrix derivative, EMD) or a combination of different technologies (graft + EMD or graft + resorbable collagen membrane). The choice of the reconstructive strategy was based on patient-related and defect-specific characteristics [29] and left to the operator's judgment. At wound closure, a horizontal internal mattress suture (Vicryl 6.0, Ethicon, Sommerville, NY) was placed between the buccal flap and the base of the attached oral papilla to ensure repositioning of the buccal flap. Wound closure was achieved by means of a second internal mattress suture (vertical or horizontal) which was placed between the most coronal portion of the flap and the most coronal portion of the oral papilla. When needed (i.e., in case of a large, thick interdental papilla), an interrupted suture was performed to ensure primary intention healing at the incision line. Primary flap closure was always obtained at suturing.

Postsurgery procedures

Sutures were removed at 2 weeks postsurgery. The patients were asked to abstain from mechanical oral hygiene procedures in the surgical area for 4 weeks. A 0.12 % chlorhexidine mouthrinse (10 mL BID/6 weeks) was used to support local plaque control. The patients were then supplemented with an antimicrobial AmF/SnF_2 mouthrinse (meridol mouthrinse, GABA International, Therwil, Switzerland) and toothpaste (meridol toothpaste, GABA International, Therwil, Switzerland) regimen. Each patient was inserted in a monthly recall program for 3 months and was reviewed according to personal needs thereafter. Each session included reinforcement of oral hygiene procedures and supragingival plaque removal. Subgingival scaling was performed following completion of the study at 6 month postsurgery.

Recordings

One calibrated masked examiner (AS) performed all the following clinical recordings.

Presurgery assessment The interdental site presenting the defect was characterized according to the following parameters:

- interdental contact point, recorded as present or absent; and
- interdental soft tissue crater, recorded as present when invagination of soft tissues was observed at the interdental col overlying the intraosseous defect.

The following measurements were performed immediately before surgery using a manual pressure sensitive probe (UNC 15, Hu-Friedy, Chicago, IL, USA) with 1-mm increments at the site showing the greatest loss of clinical attachment:

- pocket probing depth (PPD), measured from the gingival margin to the bottom of the pocket;
- local bleeding score (BS), recorded as positive when bleeding on probing was present at the surgical site;
- clinical attachment level (CAL), measured from the cemento–enamel junction (CEJ) to the bottom of the pocket; and
- gingival recession (REC), measured from the CEJ to the gingival margin.

The gingival recession was also recorded at the buccal aspect of the tooth presenting the intraosseous defect (bREC). The amount of interdental keratinized tissue (iKT) was measured as the distance from the tip of the interdental papilla to the mucogingival junction.

On digital photographs showing the buccal aspect of the tooth presenting the intraosseous defect and taken as much perpendicular as possible to the long axis of the tooth, the tip of the papilla (A) was first identified. Lines were then traced passing through A and tangent to the profile of the crowns of the teeth adjacent to the intraosseous defect to identify reference points (B_1 and B_2) (Fig. 2). The following measurements were obtained in millimeters:

- width of the interdental papilla (pW), the distance between B_1 and B_2; and

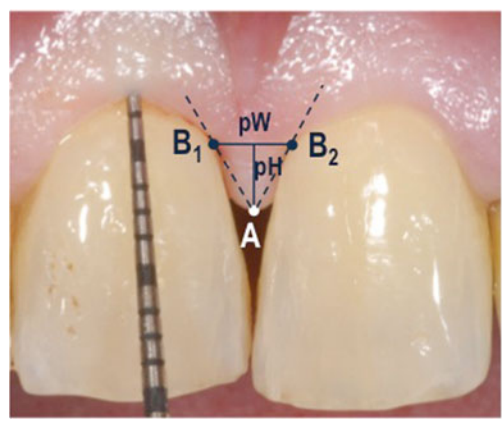

Fig. 2 Assessment of papillary width (*pW*) and height (*pH*). On digital photographs showing the buccal aspect of the tooth presenting the intraosseous defect and taken as much perpendicular as possible to the long axis of the tooth, lines were then traced passing through the tip of the papilla (*A*) and tangent to the profile of the crowns of the teeth adjacent to the intraosseous defect to identify reference points (B_1 and B_2). *pW* was measured in millimeters as the distance between B_1 and B_2. *pH* was measured as the distance between *A* and the midpoint of the line connecting B_1 and B_2. To account for photographic magnification, *pW* and *pH* were referred to the increments of the UNC 15 probe as depicted in the same photograph

– height of the interdental papilla (pH), the distance between A and the midpoint of the line connecting B_1 and B_2.

To account for photographic magnification, pW and pH were referred to the increments of the UNC 15 probe as depicted in the same photograph (Fig. 2).

Intrasurgery assessments The distance between the tip of the interdental papilla and the papillary incision margin at the interdental site (T-I) was measured using a UNC 15 periodontal probe.

At the completion of the intrasurgical debridement, the following parameters were assessed:

– configuration of the intraosseous defect (i.e., number of walls); and
– depth of the intrabony component (IBD), measured with a UNC 15 periodontal probe as the distance between the deepest point of the defect and the most coronal point of the alveolar crest.

Postsurgery assessments At suture removal, performed at 2 weeks postsurgery, the following parameters were assessed:

– membrane exposure, biomaterial exfoliation, and other complications; and
– early wound healing of the incision at the level of the interdental papilla, evaluated according to the EHI [12] as reported in the following scale: (1) complete flap closure, no fibrin line in the interproximal area; (2) complete flap closure, fine fibrin line in the interproximal area; (3) complete flap closure, fibrin clot in the interproximal area; (4) incomplete flap closure, partial necrosis of the interproximal tissue; and (5) incomplete flap closure, complete necrosis of the interproximal tissue. Intraexaminer agreement for EHI recordings, as assessed on a sample of 34 defect sites and expressed as Kendall τ coefficient, was 0.97.

At 6 months after surgery, PPD, BS, CAL, REC, and bREC were assessed.

Statistical analysis

The statistical analysis was performed at the Department of Clinical and Experimental Medicine, University of Ferrara, by an operator (AC) expert in the elaboration of data from studies in the periodontal field. A statistical software (STATISTICA; StatSoft, Italia s.r.l., Vigonza, Italy) was used for data analysis.

Descriptive statistics on early postoperative healing was based on the entire defect population (n=43). However, to assess the association between EHI and patient-related and site-specific characteristics, the patient was considered as the statistical unit. Therefore, in patients contributing two ore more defect sites, only one defect site was selected at random and considered for analysis. EHI was regarded as the primary outcome variable. The patient-related (age, gender, smoking status, and diabetic status) and site-specific characteristics (tooth type, presence of interdental contact point, pW, pH, iKT, supracrestal component of the pocket, presence of interdental soft tissue crater, IBD, and defect configuration with respect to the number of bony walls) as well as the technical aspects (T-I, additional use of a reconstructive technology) were regarded as influencing (independent) variables. Patients were categorized according to EHI (=1, >1, >2, or >3). In order to assess which factors were associated with optimal wound healing, patients with EHI=1 were compared to patients with EHI>1. Similarly, patients with EHI=1 and patients with EHI>3 were compared to determine which variables were associated with wound failure. Six-month changes in CAL, PPD, REC, and bREC were also calculated and referred to EHI.

Data were expressed as mean ± standard deviation (SD). Comparisons were performed using the χ^2 test or the two-tailed Fisher's exact test and the Student's t test for independent observations. Odds ratios were calculated for factors which were significantly associated with optimal wound healing (EHI=1 vs. EHI>1). Such factors were also entered into a multiple regression model to explain the variability in early soft tissue healing. Level of significance was set at 5 %.

Results

Study population

Thirty-five patients [24 males and 11 females; mean age, 51.4±8.5 years; age range, 34–65 years; two poorly controlled type I diabetes (i.e., HbA1c≥7.0 % at the last exam prior to surgery); seven current smokers, and four former smokers] were included in the study. Two patients assumed antiaggregants (Cardioaspirin® 100 mg; Bayer S.p.A., Milan, Italy). Patients contributed 43 intraosseous defects. In all cases, buccal SFA ensured an adequate surgical access for root and defect instrumentation. Twenty-eight patients contributed 1 defect, six patients contributed 2 defects, and one patient contributed 3 defects. Defect characteristics are summarized in Table 1.

Twenty-five defects (18 patients) were left to spontaneous healing, whereas in 18 defects (17 patients) different reconstructive technologies were associated to SFA (Table 2). All patients complied with the recall program until the 6-month visit.

Table 1 Characteristics of the defect sites as assessed immediately before and during surgery

	Incisors (*n*)	Canines (*n*)	Premolars (*n*)	Molars (*n*)
Tooth type	14	18	7	4
	Positive/present (*n*)		Negative/absent (*n*)	
Interdental contact point	26		17	
Interdental soft tissue crater	12		31	
	Mean	SD	Min	Max
pW	5.0	1.6	2.0	11.0
pH	3.5	1.4	0.5	7.5
iKT	9.3	2.3	4.0	14.0
	Combined 1/2 wall (*n*)	2 wall (*n*)	Combined 2/3 wall (*n*)	3 wall (*n*)
Defect configuration	4	3	26	10

pW width of the interdental papilla, *pH* height of the interdental papilla, *iKT* interdental keratinized tissue

Early postoperative healing

EHI was 1.9±1.1 and ranged from 1.0 to 4.0. Thirty-six sites exhibited a complete wound closure at 2 weeks, showing EHI=1 (23 defects), EHI=2 (nine defects), or EHI=3 (four defects). Seven defects showed an incomplete flap closure (EHI=4). None of the defects showed EHI=5. For sites where SFA was associated with a reconstructive technology, no evidence of membrane exposure or exfoliation of the biomaterial were either observed by the clinical examiner or referred by the patient at the 2-week visit.

Factors associated with early postoperative healing

Factors associated with early postoperative healing are reported in Table 3. No association between EHI and age, gender, or smoking status was observed. The two sites in the two diabetic patients showed EHI of 1 and 3, respectively. The four sites in the two patients assuming antiaggregants showed EHI of 1.

When compared to patients exhibiting EHI=1, patients with either EHI>1 or EHI>3 showed a significantly more frequent presence of interdental contact point and interdental soft tissue crater and lower pW (Table 3 and Fig. 3). Moreover, patients with EHI>3 showed a significantly different distribution according to tooth type (i.e., a greater proportion of posterior teeth) than patients with EHI=1 (Table 3). The presence of the interdental contact point, the presence of an interdental soft tissue crater, and pW<5 mm were significantly associated with an increased risk of having EHI>1 (Table 4). When site-specific characteristics associated with early wound healing (EHI=1 vs EHI>1) (i.e., presence of interdental contact point, presence of interdental soft tissue crater, pW) were entered into a multiple regression analysis, the model was statistically significant ($p<0.001$, $R^2=0.47$).

Early postoperative healing and 6-month outcomes

At 6 months, treatment resulted in a significant CAL gain as well as a significant PPD reduction ($p<0.001$ for both comparisons). Also, significant increases in REC and bREC were observed at 6 months compared to presurgery ($p=0.004$ and $p=0.016$, respectively) (Table 5). The number of patients showing CAL loss or no change in CAL, CAL gain 1/2 mm, CAL gain 3/4 mm, or CAL gain ≥ 5 mm was 3, 6, 15, and 11, respectively. At 6 months, 74.3 % of patients (26 over

Table 2 Treatment approaches

Treatment approach associated with buccal SFA	*n* of defects (*N*=43)	*n* of patients (*N*=35[a])
Spontaneous healing	25	18
Hydroxyapatite-based graft[b] + resorbable collagen membrane[c]	7	7
Hydroxyapatite-based graft[b]	6	6
Enamel matrix derivative (EMD)[d]	3	3
Hydroxyapatite-based graft[b] + EMD[d]	2	2

[a] One patient received a hydroxyapatite-based graft in one site and a combination of a hydroxyapatite-based graft and EMD in another site

[b] Bio-Oss® spongiosa granules 0.25–1.0 mm (Geistlich Pharma, AG, Wolhusen, Switzerland) or Biostite® (GABA Vebas, S. Giuliano Milanese, Milan, Italy)

[c] Paroguide®, GABA Vebas, S. Giuliano Milanese, Milan, Italy

[d] Emdogain® gel, Straumann, Basel, Switzerland

Table 3 Characterization of patients with EHI =1, >1, >2, and >3

	EHI					
	=1	>1	*p* value (=1 vs >1)	>2	>3	*p* value (=1 vs >3)
Distribution according to EHI (1/2/3/4/5)	17/0/0/0/0	0/8/3/7/0	–	0/0/3/7/0	0/0/0/7/0	–
Number	17	18	–	10	7	–
Patient-related factors						
Age (years)	53.1 (±7.9)	49.8 (±9.0)	0.260	47.1 (±9.1)	47.3 (±7.6)	0.117
Gender (males/females)	11/6	13/5	0.725	9/1	7/0	0.130
Smoking status (current smokers/former smokers/never smoked)	2/2/13	5/2/11	0.522	3/2/5	2/1/4	0.642
Site-specific characteristics						
Tooth type (incisors + canines/premolars/molars)	15/2/0	10/4/4	0.055	4/3/3	2/3/2	0.005
Interdental contact point (present/absent)	5/12	15/3	0.002	8/2	6/1	0.023
pW (mm)	5.8 (±1.7)	4.4 (±1.5)	0.011	4.3 (±1.5)	3.8 (±1.1)	0.004
pH (mm)	3.9 (±1.2)	3.1 (±1.7)	0.140	3.5 (±2.0)	3.1 (±1.8)	0.304
iKT (mm)	9.7 (±2.6)	8.6 (±1.9)	0.171	8.6 (±2.3)	7.9 (±2.3)	0.116
Supracrestal component of the pocket (PPD-IBD) (mm)	2.2 (±2.3)	3.1 (±2.4)	0.312	2.9 (±2.9)	2.9 (±3.4)	0.672
Interdental soft tissue crater (present/absent)	2/15	9/9	0.027	5/5	4/3	0.038
IBD (mm)	6.5 (±2.8)	5.9 (±2.5)	0.516	5.6 (±1.6)	5.3 (±1.8)	0.210
Defect configuration (mainly 2–3 wall/mainly 1–2 wall)	15/2	13/5	0.402	8/2	6/1	1
Technical aspects						
Distance between the tip of the papilla and the incision margin (T-I) (mm)	3.2 (±1.2)	2.9 (±1.9)	0.560	3.3 (±2.1)	3.3 (±2.4)	0.913
Additional reconstructive technology (none/graft + membrane/other)	11/2/4	7/5/6	0.330	3/4/3	2/3/2	0.174

pW width of the interdental papilla, *pH* height of the interdental papilla, *iKT* interdental keratinized tissue, *IBD* depth of the intrabony component

Fig. 3 Presurgery view of cases showing EHI 1, 2, 3, and 4 at 2 weeks

35 patients) showed a PPD≤4. The frequency of BS-positive patients shifted from 26, as assessed immediately before surgery, to 13, as assessed at 6 months postsurgery (p=0.002).

No statistically significant difference in the changes of CAL, PPD, REC, and bREC were observed between patients with EHI=1 and either patients with EHI>1 or EHI>3 (Table 6).

Discussion

The present study was performed to evaluate the early postoperative healing following buccal SFA for the treatment of deep intraosseous periodontal defects. Also, the association between EHI and (a) patient-related and site-specific characteristics as well as technical (surgical) factors, and (b) 6-month clinical outcomes was evaluated. Forty-three intraosseous defects in 35 patients were accessed with SFA as a standalone protocol or in combination with a reconstructive technology. Primary flap closure was obtained at suturing in 100 % of sites. A semiquantitative assessment of postoperative wound healing was performed at 2 weeks using the EHI [12]. Within their limits, the results of the study indicate that (a) SFA resulted in a complete wound closure at 2 weeks in the great majority of sites; (b) a significantly more frequent presence of interdental contact point and interdental soft tissue crater, and narrower base of the interdental papilla were observed in groups with either EHI>1 or EHI>3 compared to the group with EHI=1, and a significantly greater proportion of posterior teeth was observed in the group with EHI>3 compared to the group with EHI=1; and (c) 2-week soft tissue healing was not associated with 6-month clinical outcomes.

In the present study, the assessment of early postoperative healing at the incision margin was performed according to EHI [12]. EHI evaluates the condition of the wound margin using a five-point scale: the scores 1–3 are compatible with complete flap closure, whereas the scores 4 and 5 indicate

Table 4 Odds ratios as calculated for site-specific characteristics impairing optimal wound healing (EHI=1 vs EHI>1)

Factor	OR	95 % CI	p value[a]
Presence of the interdental contact point	12.0	1.9–88.7	0.002
Presence of an interdental crater	7.5	1.1–65.1	0.027
pW<5 mm	11.4	1.9–80.2	0.002

pW papillary width

[a] Two-tailed Fisher's exact test

Table 5 Clinical parameters as assessed immediately before and 6 months after surgery

	Presurgery (mean (±SD))	6 months (mean (±SD))	p value	Change[a] (mean (±SD))
CAL	10.4 (±2.6)	7.0 (±2.4)	<0.001	3.4 (±2.0)
PPD	8.9 (±2.0)	4.2 (±1.3)	<0.001	4.7 (±2.0)
REC	1.5 (±1.4)	2.8 (±2.1)	0.004	1.3 (±1.4)
bREC	1.2 (±1.5)	2.2 (±1.8)	0.016	1.0 (±1.3)

CAL clinical attachment level, *PPD* pocket probing depth, *REC* gingival recession, *bREC* gingival recession at the buccal aspect

[a] Positive change values indicate CAL gain, PPD reduction, REC, and bREC increases

Table 6 Six-month change in clinical parameters in patients with different early wound healing (as assessed by the EHI)

	EHI					
	=1	>1	*p* value (=1 vs >1)	>2	>3	*p* value (=1 vs >3)
Distribution according to EHI (1/2/3/4/5)	17/0/0/0/0	0/8/3/7/0	–	0/0/3/7/0	0/0/0/7/0	–
Number	17	18	–	10	7	–
Clinical parameters						
CAL change (mm)	3.3 (±2.4)	3.6 (±1.7)	0.742	3.2 (±1.9)	3.0 (±1.5)	0.696
PPD change (mm)	4.6 (±2.4)	4.8 (±1.7)	0.790	4.4 (±1.9)	4.1 (±2.0)	0.642
REC change (mm)	1.3 (±1.7)	1.2 (±1.2)	0.885	1.2 (±1.1)	1.1 (±1.2)	0.809
bREC change (mm)	0.6 (±1.5)	1.3 (±0.9)	0.149	1.6 (±0.9)	1.6 (±0.9)	0.086

CAL clinical attachment level, *PPD* pocket probing depth, *REC* gingival recession, *bREC* gingival recession at the buccal aspect

partial or complete tissue necrosis leading to incomplete flap closure. Although EHI has never been validated either clinically or histologically, this semiquantitative scale currently represents the only available method to objectively determine the early healing phase of a periodontal wound. Noteworthy, the relevance of EHI as either clinical endpoint or predictor on the outcomes of a regenerative procedure had never been investigated.

SFA showed substantial reconstructive outcomes when used alone or in association with different reconstructive technologies [13, 14, 26, 27] and appeared to be at least similarly effective compared to conservative two-flap papilla preservation techniques [14]. The rationale for the application of the SFA resides in the preservation of an intact interdental papilla, which may facilitate flap repositioning and suturing, thus optimizing wound closure for primary intention healing, as well as accelerate the re-establishment of the local vascular supply. Previous studies where a similar flap design was used to provide access for endodontic surgery in periodontally healthy patients showed a high incidence of sites healed by primary intention [30]. In our material, 36 over 43 (83.7 %) sites overlying deep intraosseous defects showed a complete flap closure at 2 weeks, with 53.5 % of sites presenting optimal wound closure (EHI=1) at clinical assessment. Consistently, when evaluating the 2-week soft tissue healing at sites accessed with a modified papilla preservation technique, Wachtel et al. [12] reported a high proportion (89–96 %) of sites showing EHI≤2. Overall, these results confirm that a minimally invasive surgical access, such as SFA [26], may be associated with a high prevalence of sites maintaining wound closure at 2 weeks following surgery even in the presence of a substantial alteration of the periodontal anatomy.

Although groups with EHI=1 and EHI>3 did not show a significantly different distribution in additional reconstructive technologies, a relevant proportion of patients treated with reconstructive devices showed a suboptimal (i.e., EHI>1) postoperative healing. On the other hand, 88.9 % of the patients treated with SFA as a stand-alone protocol showed successful soft tissue healing (EHI 1/3). This finding seems to suggest an effect of placing different biomaterials on periodontal wound healing following a standardized approach for the treatment of intraosseous defects such as SFA. It is possible to hypothesize that the adjunctive use of reconstructive devices may reduce the probability to obtain optimal early healing at sites accessed in accordance with the SFA principles. The results from previous studies evaluating the early postoperative healing of sites approached with SFA in combination with the use of a graft biomaterial + membrane support this consideration [13]. The presence of a membrane may result in a transient impairment of the revascularization process of the gingival flap during the early phase of healing [31]. In this respect, a relationship between reduced blood perfusion in a mucoperiosteal flap covering a membrane and the incidence of wound dehiscences has been reported [32]. Obviously, the influence of reconstructive devices on early wound healing following SFA needs to be explored in specifically designed controlled clinical trials.

No association between EHI and age, gender, or smoking status was observed. In contrast with our finding, a delayed and impaired healing process following gingival biopsies was observed in older compared with younger patients [33]. The effect of age on the early healing of gingival incision wounds and its clinical relevance on the reconstructive outcomes need to be further investigated since there is wide consensus that wound healing is negatively affected by the aging process [34, 35].

Higher risk for suboptimal wound closure was associated with a narrower base of the interdental papilla and the presence of either interdental contact point or interdental soft tissue crater. At the buccal aspect, blood vessels in the gingival tissues are oriented mainly in an apical-coronal direction [36]. A horizontal incision performed in the gingiva results in a transient reduction of blood perfusion to the gingival tissues coronal to the incision margin [36, 37]. When considering the characteristics of the vascular system of the interdental tissues, which consists of a mixed pattern of anastomosing capillaries and loops [38], it is therefore reasonable to admit that the dimensions as well as the morphological charactersitics of the soft tissues occupying the interdental space may affect the re-establishment of the normal blood perfusion after gingival incision.

Our interest in the evaluation of factors associated with early postoperative healing of gingival wounds is based on the importance of early wound stability for periodontal healing following flap elevation [1, 3, 4, 9, 39, 40]. Our exploratory analysis, however, showed no significant differences in terms of a 6-month CAL gain and PPD reduction at sites with EHI=1 versus sites with EHI either >1 or >3. Although the additional use of specific reconstructive technologies may influence the early postoperative healing, it is reasonable to hypothesize that such technologies may exert their beneficial effect on the regenerative process [41–45] which become clinically manifest at longer term. In this respect, the potential negative effect on early wound healing can be compensated by a clinical and histological beneficial effect at longer observation intervals as stressed in our previous study [13]. On the other hand, the fact that different outcomes in terms of early wound healing have been observed following different reconstructive strategies also indicate that this flap approach may be more indicated when some, and not other, reconstructive technologies are used. It should also be considered that sites with wound dehiscence were resolved within 1-month postsurgery in absence of manifest membrane exposure or graft exfoliation. Therefore, the observed dehiscences may have exerted a limited detrimental effect on 6-month outcomes. On the other hand, it may well be that EHI could not be sensible enough to detect substantial differences in early postoperative healing that would significantly affect the 6-month results. Previous studies where a significant effect of early wound healing on the regenerative outcome had been observed, the definition of "wound failure" by far exceeded the severity of the clinical conditions included in the EHI score [4, 46–48]. Further studies on large cohorts are therefore needed to validate the EHI as a methodology tool to assess the impact of early wound healing on clinical endpoints of periodontal regenerative surgery. Also, a potential counfounding effect due to patient-related and site-specific factors, other than EHI, that have been shown to affect the reconstructive endpoints [48, 49] cannot be excluded.

In the present study, only intraosseous defects accessed with a buccal SFA were considered for analysis. SFA with a buccal approach is indicated in intraosseous defects involving the interproximal aspect and exhibiting limited to no extension on the lingual/palatal side and when buccal access allows an appropriate root and defect debridement and the application of the proper reconstructive technology. A previous study demonstrated that, in interproximal intraosseous defects, the oral bone crest is often higher than the buccal bone crest [50]. Therefore, the data reported in the present study can be considered representative of a common clinical condition suitable for the application of the SFA. Obviously, an SFA based on a buccal flap provides better surgical access for soft tissue management, root/defect debridement and grafting, membrane positioning, and suturing procedures compared to an SFA with an oral approach. The present study design did not allow the exclusion of different outcomes that could be obtained with SFA if an oral approach had been used.

Within the limitations of the study, the present results indicate that buccal SFA may result in highly predictable (>80 %) complete flap closure and a substantial (about 50 %) prevalence of sites with optimal healing at 2 weeks following surgery. Our findings also indicate that local, site-specific characteristics may influence the early postoperative healing of the papillary incision.

Acknowledgments This study was supported by the Research Centre for the Study of Periodontal and Peri-Implant Diseases, University of Ferrara, Italy, and by a grant from Regione Emilia-Romagna (Programma Ricerca Regione-Università 2007–2009).

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Linghorne WJ, O'Connell DC (1950) Studies in the regeneration and reattachment of supporting structures of the teeth; soft tissue reattachment. J Dent Res 29:419–428
2. Yumet JA, Polson AM (1985) Gingival wound healing in the presence of plaque-induced inflammation. J Periodontol 56:107–119
3. Wikesjö UM, Nilvéus R (1990) Periodontal repair in dogs: effect of wound stabilization on healing. J Periodontol 61:719–724
4. Haney JM, Nilvéus RE, McMillan PJ, Wikesjö UM (1993) Periodontal repair in dogs: expanded polytetrafluoroethylene barrier membranes support wound stabilization and enhance bone regeneration. J Periodontol 64:883–890
5. Wikesjö UM, Nilvéus RE, Selvig KA (1992) Significance of early healing events on periodontal repair: a review. J Periodontol 63:158–165
6. Polimeni G, Xiropaidis AV, Wikesjö UM (2006) Biology and principles of periodontal wound healing/regeneration. Periodontol 2000 41:30–47
7. Hiatt WH, Stallard RE, Butler ED, Badgett B (1968) Repair following mucoperiosteal flap surgery with full gingival retention. J Periodontol 39:11–16
8. Werfully S, Areibi G, Toner M, Bergquist J, Walker J, Renvert S, Claffey N (2002) Tensile strength, histological and immunohistochemical observations of periodontal wound healing in the dog. J Periodontal Res 37:366–374
9. Wikesjö UM, Crigger M, Nilvéus R, Selvig KA (1991) Early healing events at the dentin-connective tissue interface. Light and transmission electron microscopy observations. J Periodontol 62:5–14
10. Trombelli L (2010) Flap design and suturing techniques to optimize reconstructive outcomes. In: Sculean A (ed) Periodontal regenerative therapy. Quintessence Publishing, New Malden, pp 241–258
11. Trombelli L, Farina R (2012) Flap design for periodontal healing. In Larjava H (ed.) Oral wound healing: cell biology and clinical management, Publisher: Blackwell-Wiley, pp 229–241

12. Wachtel H, Schenk G, Böhm S, Weng D, Zuhr O, Hürzeler MB (2003) Microsurgical access flap and enamel matrix derivative for the treatment of periodontal intrabony defects: a controlled clinical study. J Clin Periodontol 30:496–504
13. Trombelli L, Simonelli A, Pramstraller M, Wikesjö UME, Farina R (2010) Single flap approach with and without guided tissue regeneration and a hydroxyapatite biomaterial in the management of intraosseous periodontal defects. J Periodontol 81:1256–1263
14. Trombelli L, Simonelli A, Schincaglia GP, Cucchi A, Farina R (2012) Single flap approach for surgical debridement of deep intraosseous defects: a randomized controlled Trial. J Periodontol 83:27–35
15. Cortellini P, Tonetti MS (2011) Clinical and radiographic outcomes of the modified minimally invasive surgical technique with and without regenerative materials: a randomized-controlled trial in intra-bony defects. J Clin Periodontol 38:365–373
16. Cortellini P, Pini Prato G, Tonetti MS (1995) Periodontal regeneration of human intrabony defects with titanium reinforced membranes. A controlled clinical trial. J Periodontol 66:797–803
17. Cortellini P, Prato GP, Tonetti MS (1995) The modified papilla preservation technique. A new surgical approach for interproximal regenerative procedures. J Periodontol 66:261–266
18. Cortellini P, Pini Prato G, Tonetti MS (1996) The modified papilla preservation technique with bioresorbable barrier membranes in the treatment of intrabony defects. Case reports. Int J Periodontics Restorative Dent 16:546–559
19. Cortellini P, Prato GP, Tonetti MS (1999) The simplified papilla preservation flap. A novel surgical approach for the management of soft tissues in regenerative procedures. Int J Periodontics Restorative Dent 19:589–599
20. Cortellini P, Tonetti MS (2001) Microsurgical approach to periodontal regeneration. Initial evaluation in a case cohort. J Periodontol 72:559–569
21. Cortellini P, Tonetti MS (2005) Clinical performance of a regenerative strategy for intrabony defects: scientific evidence and clinical experience. J Periodontol 76:341–350
22. Cortellini P, Tonetti MS (2007) A minimally invasive surgical technique with an enamel matrix derivative in the regenerative treatment of intra-bony defects: a novel approach to limit morbidity. J Clin Periodontol 34:87–93
23. Cortellini P, Tonetti MS (2007) Minimally invasive surgical technique and enamel matrix derivative in intra-bony defects. I: Clinical outcomes and morbidity. J Clin Periodontol 34:1082–1088
24. Cortellini P, Nieri M, Prato GP, Tonetti MS (2008) Single minimally invasive surgical technique with an enamel matrix derivative to treat multiple adjacent intra-bony defects: clinical outcomes and patient morbidity. J Clin Periodontol 35:605–613
25. Cortellini P, Tonetti MS (2009) Improved wound stability with a modified minimally invasive surgical technique in the regenerative treatment of isolated interdental intrabony defects. J Clin Periodontol 36:157–163
26. Trombelli L, Farina R, Franceschetti G (2007) Single flap approach in periodontal reconstructive surgery (article in Italian). Dental Cadmos 8:15–25
27. Trombelli L, Farina R, Franceschetti G, Calura G (2009) Single flap approach with buccal access in periodontal reconstructive procedures. A case series. J Periodontol 80:353–360
28. O'Leary TJ, Drake RB, Naylor JE (1972) The plaque control record. J Periodontol 43:38
29. Trombelli L (2005) Which reconstructive procedures are effective for treating the periodontal intraosseous defect? Periodontol 2000 (37):88–105
30. Velvart P (2002) Papilla base incision: a new approach to recession-free healing of the interdental papilla after endodontic surgery. Int Endod J 35:453–460
31. Vergara JA, Quiñones CR, Nasjleti CE, Caffesse RG (1997) Vascular response to guided tissue regeneration procedures using nonresorbable and bioabsorbable membranes in dogs. J Periodontol 68:217–224
32. Zanetta-Barbosa D, Klinge B, Svensson H (1993) Laser Doppler flowmetry of blood perfusion in mucoperiosteal flaps covering membranes in bone augmentation and implant procedures. A pilot study in dogs. Clin Oral Implants Res 4:35–38
33. Holm-Pedersen P, Löe H (1971) Wound healing in the gingiva of young and old individuals. Scand J Dent Res 79:40–53
34. Ashcroft GS, Mills SJ, Ashworth JJ (2002) Ageing and wound healing. Biogerontology 3:337–345
35. Gosain A, DiPietro LA (2004) Aging and wound healing. World J Surg 28:321–326
36. Mörmann W, Meier C, Firestone A (1979) Gingival blood circulation after experimental wounds in man. J Clin Periodontol 6:417–424
37. Retzepi M, Tonetti M, Donos N (2007) Comparison of gingival blood flow during healing of simplified papilla preservation and modified Widman flap surgery: a clinical trial using laser Doppler flowmetry. J Clin Periodontol 34:903–911
38. Kohl JT, Zander HA (1961) Morphology of interdental gingival tissues. Oral Surg Oral Med Oral Pathol 14:287–295
39. Wirthlin MR, Yeager JE, Hancock EB, Gaugler RW (1980) The healing of gingival wounds in miniature swine. J Periodontol 51:318–327
40. Polson AM, Proye MP (1983) Fibrin linkage: a precursor for new attachment. J Periodontol 54:141–147
41. Trombelli L, Heitz-Mayfield LJ, Needleman I, Moles D, Scabbia A (2002) A systematic review of graft materials and biological agents for periodontal intraosseous defects. J Clin Periodontol 29(Suppl 3):117–135, discussion 160–162
42. Needleman IG, Worthington HV, Giedrys-Leeper E, Tucker RJ (2006) Guided tissue regeneration for periodontal infra-bony defects. Cochrane Database Syst Rev 19:CD001724
43. Esposito M, Grusovin MG, Papanikolaou N, Coulthard P, Worthington HV (2009) Enamel matrix derivative (Emdogain (R)) for periodontal tissue regeneration in intrabony defects. Cochrane Database Syst Rev 7:CD003875
44. Trombelli L, Farina R (2008) Clinical outcomes with bioactive agents alone or in combination with grafting or guided tissue regeneration. J Clin Periodontol 35(8 Suppl):117–135
45. Tu YK, Needleman I, Chambrone L, Lu HK, Faggion CM Jr (2012) A Bayesian network meta-analysis on comparisons of enamel matrix derivatives, guided tissue regeneration and their combination therapies. J Clin Periodontol 39:303–314
46. Selvig KA, Kersten BG, Chamberlain AD, Wikesjö UM, Nilvéus RE (1992) Regenerative surgery of intrabony periodontal defects using ePTFE barrier membranes: scanning electron microscopic evaluation of retrieved membranes versus clinical healing. J Periodontol 63:974–978
47. Sigurdsson TJ, Hardwick R, Bogle GC, Wikesjö UM (1994) Periodontal repair in dogs: space provision by reinforced ePTFE membranes enhances bone and cementum regeneration in large supraalveolar defects. J Periodontol 65:350–356
48. Trombelli L, Kim CK, Zimmerman GJ, Wikesjö UM (1997) Retrospective analysis of factors related to clinical outcome of guided tissue regeneration procedures in intrabony defects. J Clin Periodontol 24:366–371
49. Tonetti MS, Prato GP, Cortellini P (1996) Factors affecting the healing response of intrabony defects following guided tissue regeneration and access flap surgery. J Clin Periodontol 23:548–556
50. Tal H (1984) The prevalence and distribution of intrabony defects in dry mandibles. J Periodontol 55:149–154