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Improved wound stability with a modified minimally invasive surgical technique in the regenerative treatment of isolated interdental intrabony defects

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Abstract

Aims: This paper describes a modified surgical approach of the minimally invasive surgical technique (modified minimally invasive surgical technique, M-MIST) and preliminarily evaluates its applicability and clinical performances in the treatment of isolated deep intrabony defects in combination with amelogenins.

Material and Methods: Twenty deep isolated intrabony defects in 20 patients were studied. Fifteen were surgically accessed with the M-MIST, while in five sites, which presented a lingual intrabony component, the conventional MIST had to be applied. The M-MIST consisted of a buccal incision of the defect-associated papilla, according to the principles of the papilla preservation techniques. Only a buccal flap was raised while the interdental papilla was left in situ. The granulation tissue filling the defect was dissected and removed, leaving the interdental and palatal tissues untouched. Root instrumentation and application of the regenerative material were performed before suturing. Primary closure of the flaps was attained with a single internal modified mattress suture. Surgery was performed with the aid of an operating microscope and microsurgical instruments.

Results: The surgical chair-time of the M-MIST-treated sites (N = 15) was 56 ± 8.64 min. Early wound healing was uneventful: primary wound closure was attained and maintained in all sites. No oedema or haematoma was noted. Patients did not report pain or discomfort. The 1-year clinical attachment level (CAL) gain was 4.5 ± 1.4 mm in defects 6 ± 1.5 mm deep. Residual probing depths (PDs) were 3.1 ± 0.6 mm. A minimal increase of 0.1 ± 0.3 mm in gingival recession between baseline and 1 year was observed.

Conclusions: M-MIST was applicable on 15 isolated interproximal defects out of 20 selected ones. It resulted in very limited patient morbidity and excellent clinical improvements. These outcomes should be confirmed in a larger study.

Key words: clinical trial; microsurgery; osseous defects; periodontal diseases; periodontal regeneration

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In the last decade, some clinical investigators have focused their interest on the development of minimally invasive surgical approaches in periodontal surgery. Harrel & Rees (1995) proposed the minimally invasive surgery (MIS) with the aim to produce minimal wounds, minimal flap reflection and gentle handling of the soft and hard tissues in periodontal surgery (Harrel & Nunn 2001, Harrel et al. 2005). Cortellini & Tonetti (2001, 2002, 2004) and Wachtel et al. (2003) tested the use of operative microscopes and microsurgical instruments to increase visual acuity and accuracy in the application of papilla

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¹Private Practice, Florence, Italy; ²European Research Group on Periodontology (ERGOPerio), Berne, Switzerland preservation flaps in periodontal regeneration.

Recently, a new surgical approach, the "minimally invasive surgical technique (MIST)", has been proposed to treat isolated intrabony defects with periodontal regeneration (Cortellini & Tonetti 2007a). The background foundations for this technique are the concepts of the (MIS, Harrel & Rees 1995) and the application of papilla preservation techniques (Cortellini et al. 1995, 1999) with a microsurgical approach (Cortellini & Tonetti 2001, 2005). Results from a cohort study in isolated deep intrabony defects showed marked improvements in terms of clinical attachment level (CAL) gains and PD reduction, associated with very limited gingival recession (Cortellini & Tonetti 2007b). The cited study also reported a very limited patient morbidity and a reduced length of the surgical procedure following application of the MIST. The same approach was effective in the treatment of multiple adjacent intrabony defects (Cortellini et al. 2008).

An enhancement of this technique, the modified minimally invasive surgical technique (M-MIST Fig. 1), has been recently designed to further reduce the surgical invasiveness, with three major objectives in mind: (1) minimize the interdental tissue tendency to collapse, (2) enhance the wound/soft tissue stability and (3) reduce patient morbidity.

The aim of the present study was to describe the "M-MIST" and preliminarily evaluate its applicability, clinical performances and patient acceptance in the treatment of isolated, interdental deep intrabony defects.

Material and Methods

Study population and experimental design

Patients with advanced periodontal disease, in general good health and presenting with at least one isolated deep, predominantly interdental intrabony defect were considered eligible for this study. Patients were included after completion of cause-related therapy consisting of scaling and root planing, motivation and oral hygiene instructions. Flap surgery for pocket elimination in sites different from the experimental ones was performed, when indicated, before the regenerative treatment. All subjects gave informed written consent.

Inclusion/exclusion criteria were as follows:

- Patients in good general health. Patients with uncontrolled or poorly controlled diabetes, unstable or lifethreatening conditions, or requiring antibiotic prophylaxis were excluded.
- 2. Defect anatomy. Presence of at least one tooth with probing pocket depth (PPD) and CAL loss of at least 5 mm associated with an intrabony defect of at least 3 mm involving predominantly the interdental space of the tooth. Teeth that presented a detectable buccal and/or a lingual intrabony component were excluded.
- 3. Smoking status. Only non-smokers were included.



Fig. 1. The modified minimally invasive surgery: a representative case. (a) A 7 mm pocket distal to the upper right cuspid is associated with 9 mm of attachment level. (b) The drawing depicts the buccal incision to gain access to the defect without interdental and lingual incisions. (c) Clinical image of the buccal incision. (d) The minimally invasive buccal flap has been reflected and the granulation tissue removed from under the interdental papilla. (e) A 4 mm two-wall intrabony defect is evident. The buccal wall is missing. (f) No incisions have been performed on the palatal side. (g) An internal modified mattress suture is positioned to close the wound. (h) Primary closure of the interdental space. (i) The internal modified mattress suture from the lingual side. (j) At 1 year a 2 mm probing depth is associated with a 5 mm clinical attachment level. (k) Baseline radiograph. (l) 1-year radiograph.



Fig. 1. Continued.

- Good oral hygiene. Full-mouth plaque score (FMPS) ≤20%.
- 5. Low levels of residual infection. Full-mouth bleeding score (FMBS) $\leq 20\%$.
- 6. Compliance. Only patients with optimal compliance, as assessed during the cause-related phase of therapy, were selected.
- 7. Endodontic status. Teeth had to be vital or properly treated with root canal therapy.

Three months after completion of periodontal therapy, baseline clinical measurements were recorded. The experimental sites were accessed with the M-MIST and carefully debrided. Measurements were taken during surgery to characterize the defect anatomy. EDTA and EMD (Emdogain, Institute Straumann AG, Basel, Switzerland) were applied on the instrumented and dried root surfaces, and flaps were sutured with modified internal mattress sutures. Patients were enrolled in a stringent postoperative supportive care programme with weekly recalls for 6 weeks, and then included in a 3-month periodontal supportive care programme for 1 year.

Clinical measurements at baseline and at the 1-year follow-up visit

The following clinical parameters were evaluated at baseline before regenerative therapy and at the 1-year follow-up visit by an independent clinician. FMPSs were recorded as the percentage of total surfaces (four aspects per tooth) that revealed the presence of plaque (O'Leary 1972). Bleeding on probing (BOP) was assessed dichotomously and FMBSs were then calculated (Cortellini et al. 1993a)

PPD and recession of the gingival margin (REC) were recorded to the nearest millimetre at the deepest location of the selected interproximal site. All measurements and BOP were taken using a pressure-sensitive manual perio-

dontal probe at 0.3 N (Brodontic probe equipped with a PCP-UNC 15 tip, Hu-Friedy, Chicago, IL, USA). CAL were calculated as the sum of PPD and REC. The radiographic defect angle of each defect was measured on a periapical radiograph, as described previously (Tonetti et al. 1993). The chair-time of each surgical procedure was recorded. Primary closure of the flaps was evaluated at completion of surgery and at weekly recalls for a period of 6 weeks, along with the potential presence/absence of oedema and/or haematoma. Patients were questioned about the subjective perception of intra-operative pain and/or discomfort at completion of surgery, and of post-operative pain and/or discomfort 1 week after surgery (Cortellini & Tonetti 2001, Tonetti et al. 2004).

Clinical characterization of the intrabony defects

Defect morphology was characterized intra-surgically in terms of the distance between the cemento-enamel junction and the bottom of the defect (CEJ-BD) and the total depth of the intrabony component of the defect (INFRA), essentially as described previously (Cortellini et al. 1993b). The defects were described as 1-, 2-, 3-wall or combination defects.

Surgical approach (M-MIST)

Flap elevation

The defect-associated interdental papilla was surgically approached either with the simplified papilla preservation flap when the width of the interdental space was 2 mm or narrower (SPPF, Cortellini et al. 1999) or the modified papilla preservation technique at interdental sites wider than 2 mm (MPPT Cortellini et al. 1995). The interdental incision (SPPF or MPPT) was extended to the buccal aspect of the two teeth adjacent to the defect. These incisions were strictly intra-sulcular to preserve the entire height and width of the gingiva, and their mesio-distal extension was kept at minimum (ideally, within the mid-buccal area of the involved teeth) to allow the reflection of a triangular buccal flap to expose the coronal edge of the buccal bone crest. The interdental papillary tissues were partially dissected in a bucco-lingual and corono-apical direction with a microblade (micro 6900, Advanced Surgical Technologies,

Sacramento, CA, USA). The microblade cut through the interdental tissues, splitting the coronal part (basically the supracrestal tissues) from the apical part (i.e. the "granulation" tissue filling the intrabony component of the defect). The micro-blade was introduced with an inclination suitable to intercept the buccal side of the lingual bone crest, as close as possible to its coronal edge, to isolate the granulation tissue filling the intrabony component of the defect from the supra-crestal, papillary tissues. No interdental and/or lingual intrasulcular incisions were performed. The supracrestal interdental tissues, therefore, remained attached to the root cement of the crest-associated tooth, continuous with the palatal tissue, and were not displaced.

Defect debridement, EMD application and suturing technique

The granulation soft tissue was dissected from the buccal and interdental bony walls with the micro-blade and carefully removed with a sharp mini curette (Gracey, Hu-Friedy) from under the papilla. The defect was debrided with the combined use of mini curettes and power-driven instruments (Soniflex Lux, Kavo, Germany) and the root was carefully planed. Special care was taken to reach all the parts of the exposed root surface and residual bony walls, partly hidden by the non-elevated lingual and papillary soft tissues. To allow instrumentation, the buccal papillary flap was slightly reflected, carefully protected with a periosteal elevator and frequently irrigated with saline. Mini-curettes and sonic instruments were also carefully inserted through the interdental pocket of the defect-associated tooth, between the preserved interdental papilla and the root surface, to reach the root surface for debridement. Care was taken to prevent any disruption of the papillary fibrous attachment to the bone crest and to the crest-associated root, in order to preserve the stability of the papilla. At the end of instrumentation, EDTA was applied on the root surface for 2 min. and then the defect area was carefully rinsed with saline. Before the application of EMD, a single modified internal mattress suture was positioned at the defect-associated interdental area (6-0 or 7-0 e-PTFE Goretex. WL Gore & Associates, Flagstaff, AZ, USA). The suture was left loose. EMD was applied on the rinsed and air-dried root surface.

Finally, the suture was tightened to reach primary closure of the defectassociated papilla (Cortellini & Tonetti 2001, 2005, 2007a, b).

When persistent bleeding was observed at the end of defect/root instrumentation, a gauze wet with saline was gently placed into the defect for 5 min. to halt bleeding before application of EDTA and EMD (Cortellini & Tonetti 2007b, Cortellini et al. 2008).

All the surgical procedures were performed with the aid of an operating microscope (Global Protege, St Louis, MO) at a magnification of $\times 4$ to $\times 16$ (Cortellini & Tonetti 2001, 2005). Microsurgical instruments were utilized, whenever needed, as a complement to the normal periodontal set of instruments.

Sites with a lingually extended defect component

When the experimental defect extended far too much on the lingual side of the involved tooth, the interdental papilla was elevated along with a lingual flap to allow a proper debridement and EMD application at the lingual side. In these cases, surgery was thereby completed following the rules of the MIST (Cortellini & Tonetti 2007a, b).

Post-operative period

Post-operative pain was controlled with ibuprofen. Patients received 600 mg at the end of the surgical procedure and were instructed to take another tablet 6 h later. Subsequent doses were taken only if necessary to control pain. Patients with contraindications to NSAIDs received 500 mg acetaminophen at surgery and after 6h. A protocol for the control of bacterial contamination consisting of systemic doxicycline (100 mg b.i.d. for 1 week), 0.12% chlorhexidine mouth rinsing three times per day and weekly prophylaxis was prescribed (Tonetti et al. 2002). Patients were requested to avoid brushing, flossing and chewing in the treated area for a periods of 2-3 weeks. Then patients resumed full oral hygiene. At the end of the "early healing phase", patients were placed on a 3month recall system for 1 year.

Data analysis

A total of 20 patients were enrolled in this case series. Five out of 20 were treated with the original MIST for reasons associated with the defect accessibility. Data were expressed as means \pm SD of 15 defects in 15 patients (M-MIST) and five defects in five patients (MIST). No data points were missing. Comparisons between baseline and 1 year CAL, PPD and REC were made using the paired Student's *t*-test ($\alpha = 0.05$). Percentage fill of the baseline intrabony component of the defect was calculated as: CAL% = (CAL gains)/INFRA × 100.

CAL gains, residual PPD and position of the gingival margin were the primary outcome variables.

Results

Experimental population and surgical approach

Twenty intrabony defects in 20 subjects (mean age 48.1 ± 10.4 , range 31-65vears, 12 females, and non smokers). who fulfilled the admission criteria. were included in this case cohort. The M-MIST was applied in 15 of the 20 selected sites (mean patient age 46.1 ± 10.3 , range 31-65 years, nine females). The remaining five sites (mean patient age 54 ± 9.0 , range 44-64 years, three females) presented defects involving the lingual side and required the elevation of the interdental papilla and the lingual flap to ensure appropriate debridement and management of the defect. The decision was taken during the surgery, after the removal of the granulation tissue from under the papilla. These defects were therefore treated with the MIST (Cortellini & Tonetti 2007a, b).

M-MIST-treated population

Patient and defect characteristics at baseline

FMPSs and FMBSs at baseline were $13.1 \pm 4.7\%$ and $5.8 \pm 3.0\%$, respectively (Table 1). CAL of 9.7 ± 1.8 and PPDs of 7.7 ± 1.5 mm on average were recorded (Table 1). The radiographic defect angle was $32.1 \pm 4.1^{\circ}$. The distance from the cemento-enamel junction to the bottom of the defect (CEJ-BD) was 11.1 ± 2.3 mm, and the intrabony component of the defects (INFRA) was 6 ± 1.5 mm (Table 1).

Design of the surgical flap and surgical chair-time

The SPPF was used in five of the 15 M-MIST-treated sites and in all the cases

Table 1. Baseline patient and defect characteristics of M-MIST treated cases (N = 15)

Variables	Mean \pm SD	Minimum	Maximum
FMPS (%)	13.1 ± 4.7	4	20
FMBS (%)	5.8 ± 3	1	11
PPD (mm)	7.7 ± 1.5	6	12
REC (mm)	2 ± 1.3	1	6
CAL (mm)	9.7 ± 1.8	7	14
CEJ-BD (mm)	11.1 ± 2.3	8	16
INFRA (mm)	6 ± 1.5	4	9
X-ray angle (deg.)	32.1 ± 4.1	25	40

FMPS, full mouth plaque score; CAL, clinical attachment level; CEJ-BD, cemento-enamel junction and the bottom of the defect; M-MIST, modified minimally invasive surgical technique; PPD, probing pocket depth.

Table 2. Clinical outcomes at baseline and 1 year after treatment of M-MIST treated cases (N = 15)

Variables	Baseline	1 year	Difference	Significance*
PPD (mm)	7.7 ± 1.5	3.07 ± 0.6	4.6 ± 1.5	p<0.0001
REC (mm)	2 ± 1.3	2.07 ± 1.3	0.07 ± 0.3	p = 0.167
CAL (mm)	9.7 ± 1.8	5.13 ± 1	4.5 ± 1.4	p<0.0001

*Paired *t*-test.

CAL, clinical attachment level; M-MIST, modified minimally invasive surgical technique; PPD, probing pocket depth.

the buccal incision was restricted to the defect-associated papilla. Vertical releasing incisions were never performed. The average M-MIST surgical chair-time was 56.5 ± 8.6 min. (range 43-69 min.).

Primary closure of the flap and post-operative period

In all treated sites, primary closure was attained at completion of the surgical procedure. All the treated sites remained closed during the 6 weeks of the early healing period. No oedema or haematoma was noted in any of the treated sites. None of the patients reported any intraoperative pain and personal feeling of hardship of the procedure at the end of surgery. At week 1, none of the patients reported significant postoperative pain. Three patients reported very limited discomfort in the first 2 days of the first post-operative week. Fourteen out of 15 described the first postoperative week as uneventful, reporting that they had no feeling of having been surgically treated after the second post-operative day.

1-year clinical outcomes (Table 2)

The 15 patients presented at the 1-year follow up visit with FMPS and FMBS of $12.2 \pm 4.4\%$ (range 5–20) and $3.7 \pm 2\%$ (range 0–7), respectively. The differences in FMPS and FMBS

between baseline and 1 year were not statistically significant (p = 0.099 and 0.055, respectively).

The 1-year CAL was 5.1 ± 1 mm with a clinical attachment gain of 4.5 ± 1.4 mm (range 3–9 mm). Differences in CAL between baseline and 1 year were clinically and statistically highly significant (p < 0.0001). The 1-year CAL% was $75.5 \pm 10\%$, with a range of 62.5% to 100%.

Residual PPDs were 3.1 ± 0.6 mm, with an average pocket depth reduction of 4.6 ± 1.5 mm. Differences between baseline and 1-year PPDs were clinically and statistically highly significant (p < 0.0001). Only three sites showed a residual PPD of 4 mm; all the other sites showed a 1-year PPD of 3 mm or less.

A minimal average change of 0.07 ± 0.3 mm in the position of the gingival margin between baseline and 1 year was observed. This difference did not reach statistical significance (p = 0.167).

MIST-treated population

Patient/defect data and 1-year outcomes that refer to the five MIST-treated cases are reported in Table 3.

The SPPF was used in three out of five MIST-treated sites. The buccal incision in three MIST cases involved an additional interdental space. The average MIST surgical chair-time was 64.8 ± 4.6 min. (range 59–70 min.).

Primary closure was attained and maintained for 6 weeks in all sites. None of the patients reported any intra-operative pain or personal feeling of the hardship of the procedure. At week 1, no oedema or haematoma was noted. Four out of five described the first postoperative week as uneventful. Only one patient reported limited postoperative pain and discomfort that lasted 3 days.

Discussion

This clinical study was designed to explore the applicability, the clinical outcomes and the patient perception of an M-MIST, an extension of the MIST, designed to further reduce surgical invasiveness in the treatment of isolated deep interdental intrabony defects.

The design of this surgical approach allows both access to root surface instrumentation and minimization of flap elevation through the elevation of the buccal flap alone. This further enhances wound stability during early wound healing and prevents the collapse of the papilla into the defect: at the end of the procedure, the buccal flap is repositioned and sutured to the interdental supracrestal soft tissues, still anchored with their fibres to the root cement. The improved stability of the soft tissues could play a positive role in increasing the stability of the blood clot, a key factor in regenerative therapy (Hiatt et al. 1968, Wikesjo & Nilveus 1990, Haney et al. 1993). In addition, the potential prevention of the interdental soft tissue collapse could preserve more space for the regeneration to occur.

On the other hand, the preservation of the "soft tissue roof" leaves a very limited buccal access to the intrabony defect. The limited access requires the use of an operating microscope or, at least, of magnifying lenses with adequate illumination, and microsurgical instruments. The granulation tissue is sharply dissected and carefully "carved" away from the intrabony component. When the defect is debrided, the buccal side of the lingual wall of the defect becomes visible: at this time, the clinician has to carefully inspect the lingual side of the defectassociated tooth to find the limits of the intrabony defect. If the intrabony

defect involves the lingual aspect, the lingual root planing becomes a very difficult exercise. In this instance, it is suggested to extend the incision to the interdental and oral crevices in order to elevate the papilla to allow a direct vision of the lingual side, performing the MIST (Cortellini & Tonetti 2007a, b).

The defect population selected for this study included only defects with a prevalent interdental intrabony component. The M-MIST was applicable in 15 of the 20 selected defects. In five sites, the conventional MIST had to be applied. As discussed above, these defects showed a consistent intrabony component extending to the lingual/ palatal side, which was detected during the procedure.

The application of the M-MIST resulted in a significant amount of CAL gain $(4.5 \pm 1.4 \text{ mm} \text{ in defects})$ with an intrabony component of 6 ± 1.5 mm) associated with a remarkable stability of the gingival margin and a very shallow residual PPD (Table 2). The percent fill of the baseline intrabony component of the defects in terms of CAL gain ranged from 62.5% to 100% (average $75.5 \pm 10\%$), in agreement with the results reported by the best evidence of more conventional and more invasive regenerative approaches (Cortellini & Tonetti 2000, 2005, Rosen et al. 2000, Murphy & Gunsolley 2003). Both the remarkable percent defect resolution and the minimal interdental soft tissue recession could support the hypothesis of a positive influence of the surgical design on the clinical outcomes, even though this case cohort does not allow any conclusion or comparison with other techniques: large comparative studies are needed to explore the potential of the proposed technique in depth.

From a patient's standpoint, this was a very well tolerated and relatively short procedure (surgical chair-time 56.5 ± 8.6 min., range 43-69 min.). Patients reported an uneventful postoperative period with very limited/no pain and discomfort.

The five cases treated with the MIST had very similar clinical outcomes, a longer surgical chair-time and very low patient morbidity; however, no comparison between the two techniques can be performed.

In summary, M-MIST associated with EMD resulted in improved clinical outcomes with no or minimal patient morbidity. It was easily applicable to isolated interproximal intrabony defects with a prevalent interdental component with no or minimal involvement of the lingual/palatal side. There exists, therefore, the need to carry out a careful diagnostic exercise before surgery to select the potential M-MIST candidates. In addition, the surgeon has to be aware of the possibility of extending the M-MIST incisions to a MIST approach to allow for better lingual visibility when needed. The very limited soft tissue elevation of the M-MIST requires the use of an operating microscope or lupe with good illumination for a direct view of the defect. In addition, it basically eliminates the use of a barrier membrane, but allows the use of any biological material, grafting material or their combination. This approach is potentially applicable as a pure flap surgery. A controlled study is ongoing to confirm and extend the reported positive preliminary outcomes and to investigate the potential of the M-MIST alone compared with use with EMD and with a

combination of EMD and a grafting material.

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Table 3. Clinical outcomes at baseline and 1 year after treatment of MIST treated cases (N = 5)

Variables	Baseline	1 year	Difference	Significance*
FMPS (%)	9.6 ± 4	9 ± 2.2	_	_
FMBS (%)	4.4 ± 2.9	4.8 ± 2.2	-	-
PPD (mm)	8 ± 1.9	3 ± 0.7	5 ± 2.4	p < 0.0001
REC (mm)	2 ± 1.2	2.2 ± 1.1	0.2 ± 0.5	p = 0.2
CAL (mm)	10 ± 2.9	5.2 ± 0.8	4.8 ± 2.4	p < 0.0001
CEJ-BD (mm)	11.2 ± 2.8	_	-	-
INFRA (mm)	6 ± 1.9	_	_	_
X-ray angle (deg.)	33.2 ± 11.1	-	-	-

*Paired *t*-test.

FMPS, full mouth plaque score; CAL, clinical attachment level; CEJ-BD, cemento-enamel junction and the bottom of the defect; M-MIST, modified minimally invasive surgical technique; PPD, probing pocket depth. A., Dubravec, D. & Adriaens, P. (2001) The simplified papilla preservation flap in the regenerative treatment of deep intrabony defects: clinical outcomes and postoperative morbidity. *Journal of Periodontology* **72**, 1702–1712.

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Clinical Relevance

Scientific rationale for the study. To improve wound stability and reduce patient morbidity, minimally invasive surgical approaches are being developed for periodontal regenerative therapy.

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Principal findings. M-MIST was applicable in most of the selected sites and its use in combination with EMD resulted in remarkable clinical improvements and very limited patient discomfort.

Practical implications. Application of M-MIST in combination with

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