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Healing response of apicomarginal defects to two guided tissue regeneration techniques in periradicular surgery: a double-blind, randomized-clinical trial

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Abstract

Marín-Botero ML, Domínguez-Mejía JS, Arismendi-Echavarría JA, Mesa-Jaramillo AL, Flórez-Moreno GA, Tobón-Arroyave SI. Healing response of apicomarginal defects to two guided tissue regeneration techniques in periradicular surgery: a double-blind, randomized-clinical trial. *International Endodontic Journal*, **39**, 368–377, 2006.

Aim To compare healing responses to periosteal sliding grafts and polyglactin 910 periodontal mesh used as guided tissue regeneration (GTR) materials/techniques when both periapical and periradicular bone loss are present.

Methodology Thirty patients with suppurative chronic apical periodontitis with apicomarginal communication were selected and allocated randomly into two groups according to the barrier technique to be used during periradicular surgery: periosteal graft group ($n = 15$) and bioabsorbable membrane group ($n = 15$). Clinical and radiological evaluations were completed prior to surgery, a week later and every 3 months after surgery up to 12 months to measure the periodontal pocket depth (PD), clinical attachment level (CAL), gingival margin position (GMP), size of periapical lesion, percentage reduction of the periapical rarefaction, and periapical healing.

Results Both groups showed highly significant ($P < 0.001$) reductions in periodontal PD, CAL and size of periapical lesion at 12 months whilst GMP was unaltered. No significant difference between the experimental groups was evident for these parameters, or for the percentage reduction of size of the periapical lesion and clinical-radiographic healing.

Conclusion Guided tissue regeneration applied to apicomarginal defects using sliding periosteal grafts and use of bioabsorbable membranes led to similar enhancements of the clinical outcome of periradicular surgery in terms of periapical healing, gain of periodontal support, PD reduction and minimal recession of the gingival margin.

Keywords: apicomarginal communication, bioabsorbable membrane, guided tissue regeneration, periosteal grafts, periradicular surgery.

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Introduction

The goal of periradicular surgery is the predictable regeneration of periapical tissues with complete restoration of the anatomy of the mucogingival complex. Generally, the prognosis of periradicular surgery varies between 25% and 90% (Gutmann & Harrison 1991) and several tooth-related factors have been identified to affect the outcome, amongst them, the amount and location of bone loss (Hirsch *et al.* 1979). When bony destruction of the pathological process includes a localized total loss of marginal bone, the prognosis for success is reported to be 37% (Skoglund & Persson 1985). The reason for the limited success has

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been identified as an ingrowth of non-osteogenic tissues into the periradicular surgical site and downgrowth of epithelial tissue along the root surface (Dahlin *et al.* 1988).

Although apicomarginal defects are infrequent they represent a significant challenge to healing resulting in different techniques being described in order to cover the diseased root surface. Since its earliest report in the literature, guided tissue regeneration (GTR) with barrier membranes has demonstrated to provide an opportunity for the progenitor cells to regenerate lost periodontal structures (Nyman *et al.* 1982, Gottlow *et al.* 1986) and different studies have shown that this technique can also be successfully applied in endodontic surgery (Baek & Kim 2001, Douthitt *et al.* 2001, Dietrich *et al.* 2003). Placement of a physical barrier (membrane) over an osseous defect can prevent the faster proliferating oral epithelium and gingival connective tissue from growing into the bone defect, allowing the cells of the periodontal ligament and endosteum to colonize the blood clot and regenerate the lost tissue (Dahlin *et al.* 1988, Nyman 1991).

The first generation of membrane barriers was made of nonbiodegradable expanded polytetrafluoroethylene (e-PTFE). However, the use of these barriers has been limited by the necessity of second surgery for membrane removal and its high exposure rate (Gotfredsen *et al.* 1993). Bioabsorbable membranes were then developed and have demonstrated comparable results to the e-PTFE membrane in experimental animal (Douthitt *et al.* 2001) and clinical human (Oh *et al.* 2003, Vandana & Vanda 2003) studies. Currently used absorbable membranes are made of collagen or of polyglycolic acid, polylactic acid, or copolymers. Polyglactin 910 is a polyglycolide-polylactide copolymer that consists of a woven mesh initially designed for nonperiodontal and submerged barrier purposes. Upon placement in tissue, significant wound support is provided for at least 14 days postoperatively. Approximately 40% of tensile strength is retained after 21 days. Absorption is minimal until approximately 42 days and essentially complete between 60 and 90 days (Hutmacher *et al.* 1996, Wang & MacNeil 1998).

Alternatively, autogenous periosteal grafts are an attractive choice to existing barrier membrane materials as they meet the requirements of an ideal material and are accepted biologically (Kwan *et al.* 1998). The periosteum is a continuous composite fibroelastic covering membrane of the bone, which it is intimately linked (Chanavaz 1995). It is described as a tissue consisting of two layers: an outer, non-osteogenic, fibrous layer and an inner, cellular, osteogenic layer, the cambium layer (Eyre-Brook 1984). Although the bone cortex is the main beneficiary of the anatomical and physiological functions of the periosteum, the behaviour of the entire bone remains closely influenced by its activity. These functions are mainly related to the cortical blood supply and osteogenesis. Through its elastic and contractile nature, it participates in the maintenance of bone shape, and plays an important role in metabolic ionic exchange and physiologic distribution of electro-chemical potential differences across its membranous structure (Chanavaz 1995). As a structure rich in osteoprogenitor cells, the periosteum can stimulate bone formation when used as a graft material in animal and human studies (Goldman & Smukler 1978, Lekovic *et al.* 1991, Ishida *et al.* 1996, Ueno *et al.* 1999, 2001). In addition, bone growth factors, such as bone morphogenic proteins (BMPs), insulin-like growth factors (IGFs), transforming growth factors beta (TGF-β), and platelet derived growth factor (PDGF), that have been effective in promoting bone regeneration in dentoalveolar defects, are localized in periosteal cells (Hollinger & Wong 1996, Schliephake 2002).

The purpose of this work was to compare the healing response to periosteal sliding grafts and polyglactin 910 periodontal mesh used as GTR materials/techniques when both periapical and periradicular bone loss is present.

Materials and methods

Study design

This prospective, double-blind, randomized-controlled clinical trial was conducted at the Faculty of Dentistry, University of Antioquia in Medellín, Colombia. The study conformed to the ethical guidelines of the Helsinki declaration and was approved by the Institutional Research Ethics Board. The study population comprised all patients referred from general dental practice and secondary referral centres for periradicular surgery with diagnosis of suppurative chronic apical periodontitis and apicomarginal communication (Fig. 1). All potential referred participants were examined at a screening session by trained research associates (GF and AM), for establishing their suitability for the study. Eligibility criteria included failed previous root canal treatment and retreatment at least 1 year previously (Lieblich 2002), post and crown in

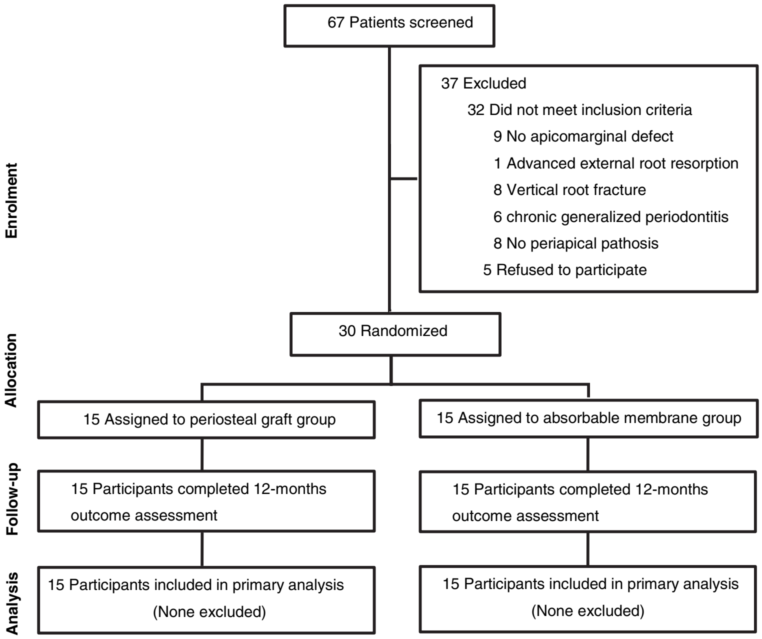

Figure 1 Flow diagram of patient progress through the phases of the randomized trial.

the tooth, failed previous surgery with persistent bony lesion, apicomarginal communication, recurrent episodes of purulent discharge, and adequate final restoration with no clinical evidence of coronal leakage. Clinical or radiographic evidence of root fracture, resorptive processes involving more than the apical third of the root, chronic generalized periodontitis, and any systemic disease contraindicating oral surgery were regarded as exclusion criteria.

Recruitment of the study was terminated at 30 patients because of slow accrual. A considerably larger sample size was hoped for but not achieved. Consent was obtained from all patients following careful explanation of the procedures used and their risks and benefits.

Preoperative procedures and primary outcome measurements

Clinical signs and symptoms were recorded preoperatively. After the initial examination and a treatment planning session, each patient received detailed instructions in proper self-performed plaque control and was subjected to a series of full mouth scaling and root planing, including occlusal adjustment in those cases where traumatic occlusion was present. One week after this initial therapy, the patients were recalled for a baseline examination. All preoperative clinical periodontal measurements were performed by a single calibrated investigator (JA) who was masked to which group the patient would be placed. The clinical parameters recorded, including periodontal pocket depth (PD), clinical attachment level (CAL) and gingival margin position (GMP), were measured on the buccal aspect of the interproximal space and the midbuccal aspect of the involved teeth (to the nearest mm) using a straight periodontal probe (PCP UNC 15; Hu-Friedy, Chicago, IL, USA). Only the site with the deepest measurements at baseline was evaluated. PD was measured from the gingival margin to the base of the defect. As a reference for the CAL and GMP measurements, the cemento-enamel junction (CEJ) or the apical border of the restoration if the CEJ was not visible were used.

The diagnostic and control radiographs were taken with the Rinn® (XCP® Instruments; Elgin, IL, USA) parallel technique and were digitized using a flat bed scanner (Genius Color Page HR6X; KYE Systems Europe, Langenfeld, Germany) with a resolution of 1200 dpi, 10-bit grey values. Two independent observers (MM and JD) performed a blind radiographic assessment of the size of periapical lesion (SPL) in mm^2, with an agreement of 95–96%, through use of an image analyzer system (AxioVision 3.1®; Carl Zeiss, Oberkochen, Germany). When discordant measurement data were reported by the examiners, new examinations were repeated, and any further controversy was resolved by discussion. All radiographs were evaluated under 10-fold magnification. Images were

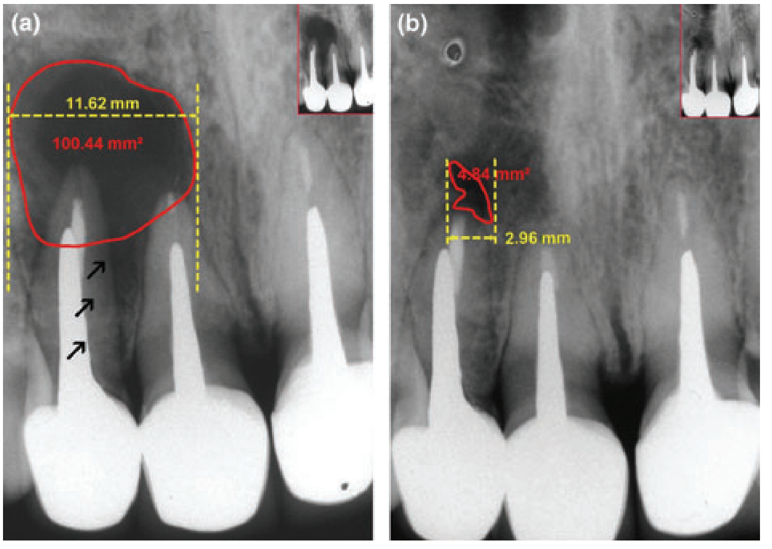

Figure 2 Digitized radiograph of the maxillary right central and lateral incisors with chronic suppurative apical periodontitis showing the before and after tracings of the bony defect (size of periapical lesion = red outline; diameter = yellow calliper). The case was treated with periosteal graft technique. (a) preoperative radiograph showing irregular periapical radiolucency at the apex of teeth 12 and 11. The tooth 12 had short root filling and a concomitant marginal lesion with communication (arrows) on the midbuccal aspect of the root. (b) Twelve-month after periradicular surgery and IRM root-end fillings, the bony defect is almost resolved with significant change in the size and shape of the radiolucent lesion (incomplete healing). Insets: lower magnification radiographs illustrating the overall actual extent of periradicular lesion prior to tracings.

calibrated using a microscope ocular micrometer (Carl Zeiss, Oberkochen, Germany) as reference, which was put into the computer program. Periapical lesion was defined as the radiolucent area located in the apical third of the root from the point at which the periodontal ligament showed a continuous width. If no periodontal ligament could be identified, the point where the projection of the alveolar crest crossed the root surface was taken as a landmark. If several bony contours could be identified, the most external outline was used as reference (Figs 2 and 3).

Randomization

Following the baseline examination, each patient was randomized using a computer-generated randomization code. Subjects were assigned to either the periosteal graft group ($n = 15$) or absorbable membrane group ($n = 15$) procedure without stratification. The randomization was developed to eliminate any bias on the part of the investigators and to balance the number of patients between the surgery types. Using a 50 : 50 randomization allocation ratio, a research associate (GF) created envelopes containing concealed assignment codes assigned sequentially to eligible patients.

Surgical techniques

All surgery was performed by a single investigator (ST) using a high resolution surgical binocular loupes (×6.0 magnification) fitted to a fibre optic headlight (Heine Optotechnik®, Herrsching, Germany). The operator was blind to which group the patient had been placed until the time of surgery. At this time, the patient's number and code were broken. The periosteal graft group, had periradicular surgery with split-thickness flap and periosteal sliding graft (Fig. 4-a,b,c) following a previously described surgical technique (Tobón-Arroyave *et al.* 2004). In the absorbable membrane group the patients had periradicular surgery with a full-thickness mucoperiosteal flap and the addition of a bioabsorbable membrane of poliglactin 910 (Vicryl® Ethicon, Brunswick, NJ, USA) placed over the entire defect (Fig. 4d,e). A non-GTR control was excluded as different studies have demonstrated a significant result favouring barrier techniques in periradicular surgery (Von Arx & Cochran 2001). In addition, cases that could have treated without the GTR or flap intervention and could have served as controls could not be allocated throughout recruitment period.

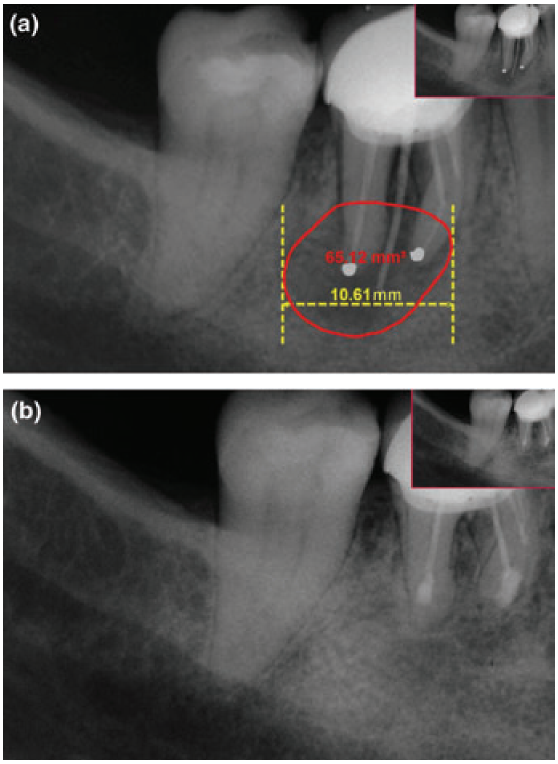

Figure 3 Radiographic images of a mandibular right first molar treated with the absorbable membrane technique. (a) Preoperative radiograph demonstrating interradicular defect extending to the apical region of the roots, amalgam apical root-end fillings, and tracings of the bony defect (size of periapical lesion = red outline; diameter = yellow calliper). (b) Twelve months follow-up radiograph showing complete resolution of the periradicular lesion. Insets: lower magnification radiographs illustrating the overall actual extent of periradicular lesion prior to tracings.

The surgical protocol was established in accordance with the following general scheme: flap reflection, osteotomy (when necessary), debridement (periradicular curettage-enucleation) of the bony lesion, planing of the exposed roots, root-end resection with diamond finishing bur (Perioset® N° 575; Intensiv, Viganello, Switzerland) at high speed, cavity preparation (2- to 3-mm deep) using diamond ultrasonic retrotips (DFy-908 double angled files with 0.8 mm shanks, ENAC-OE505S®; Osada Electric Co. Ltd., Los Angeles, CA, USA), root-end filling with IRM® (Caulk-Dentsply, Mildford, DE, USA), placement of periosteal graft or absorbable membrane (according to the experimental group) extending beyond the defects margins, and wound closure with interrupted nonabsorbable silk sutures.

Postoperative care

The sutures were removed between 7 and 10 days after the operation and then clinical and radiographic controls were performed every 3 months up to 12 months by assessing the same parameters as baseline except that PD, CAL and GMP were not measured until 12 months. Routine examination procedures were used to evaluate any evidence of signs and/or symptoms. Furthermore, each periapical lesion was evaluated on the radiograph for the percentage reduction at these time intervals. These measurements and the qualitative changes generated in the periapical rarefaction were used to assign each case to the categories of radiographic healing described by Rud *et al.* (1972).

Statistical analysis

Data were analysed using SPSS 12.0® (SPSS Inc., Chicago, IL, USA). Results were expressed as the mean (SD). Because the results for each group did not follow a normal distribution, the variables were analysed using nonparametric methods, the Mann–Whitney and Wilcoxon rank sum tests for unpaired and paired data. The difference between groups in degree of healing at 12 months was quantified by the overlap measure U/mn (Newcombe 2006) with a 95% confidence interval.

Results

Between January 2000 and August 2003, a total of 67 patients were screened for entry to the study. Thirty-two patients were subsequently excluded because they did not fulfil entry criteria and five who met the screening criteria chose not to enrol (Fig. 1). Finally, a total of 30 patients aged 19–70 in good general health with suppurative chronic apical periodontitis and apicomarginal communication were randomized. The graft group comprised seven males and eight females, with mean age 43.7 (SD 12.6). The absorbable membrane group were similar, comprising four males and 11 females, with mean age 38.9 (SD 10.4). Lesions affected one or more apices and maximum diameter ranged from 5 to 12 mm. Fourteen surgical sites were in anterior and 16 in posterior teeth; 22 were maxillary and eight mandibular.

Immediate postoperative healing proceeded uneventfully for all defects; specifically, no membrane exposures or any other unfavourable effects were clinically evident. Table 1 shows baseline and 12-month postoperative

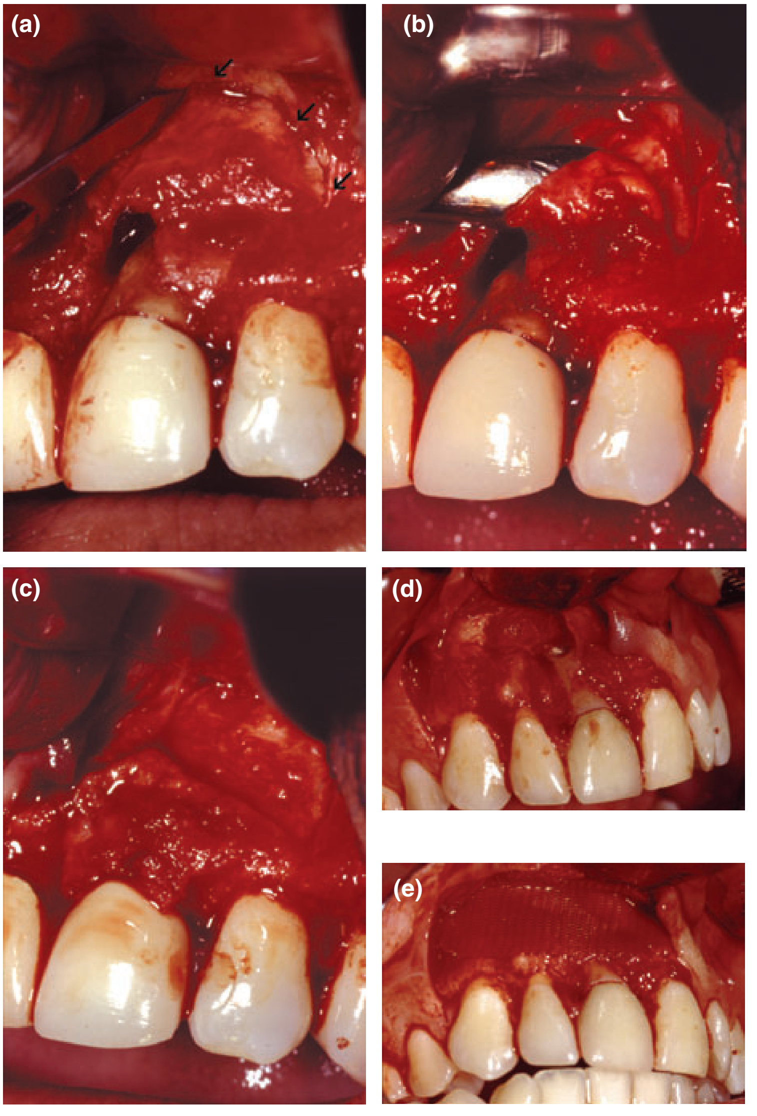

Figure 4 Surgical procedures carried out in the experimental group. In both cases partial destruction of the buccal cortical plate of bone and total denudation of the buccal surface of the root are evident after granulomatous tissue has been removed. Maxillary left central incisor treated with periosteal graft technique: (a) incision of the connective tissue around the defect to obtain a graft which includes periosteum is apparent (arrows). (b) An autogenous periosteal graft of appropriate shape and size is raised. (c) The periosteal graft is placed over the entire defect. Maxillary right central incisor treated with the absorbable membrane technique: (d) large bone defect showing an apical pathosis with communication to the alveolar crest. (e) Placement of membrane (poliglactin 910) over the entire defect.

results by treatment group. PD, CAL and SPL reduced highly significantly during the 12-month follow-up period ($P < 0.001$ in each treatment group, Wilcoxon test). GMP values were predominantly negative and became slightly more so by 12 months ($P = 0.88$ and 0.96 in graft and membrane groups respectively). That is, the gingival margin gradually receded from its coronal position in both treatment groups. Changes in all parameters did not differ significantly between the two experimental groups.

Table 2 shows the percentage reduction of SPL at 3-month intervals postsurgery by group. In both groups, there was a similar tendency towards reduction of the size of the lesion. Only a marginally significant difference between groups was observed at the 3-month observation period ($P = 0.059$).

For combined clinical-radiographic healing by groups, at 12 months after surgery (Table 3), 13 cases with clinically complete and 13 with incomplete healing also fulfilled the corresponding radiographic criteria. Two cases in the absorbable membrane group with sinus tract formation, evidence of suppuration, discomfort, and no improvement in the size of the radiolucency were categorized as unsatisfactory healing, i.e. failure. Conversely, two cases in the periosteal graft group with persistent mobility and tenderness to percussion and palpation, despite qualitative changes noted in the apicomarginal rarefaction

Table 1 Mean (SD) periodontal pocket depth (PD), clinical attachment level (CAL), gingival margin position (GMP) and size of periapical lesion (SPL) at baseline and 12 months postsurgery by experimental group

		Experimental group	
Parameters	Time interval	Periosteal graft (n = 15) mean (SD)	Absorbable membrane (n = 15) mean (SD)
PD	Baseline	8.1 (3.7)	7.8 (3.2)
	12 months	1.8 (0.5)	2.0 (0.6)
CAL	Baseline	8.6 (2.5)	8.4 (3.1)
	12 months	2.6 (1.5)	2.8 (1.3)
GMP	Baseline	−0.6 (1.2)	−0.6 (1.3)
	12 months	−0.8 (0.9)	−0.8 (1.0)
SPL (mm^2)	Baseline	62.6 (39.0)	50.0 (17.9)
	12 months	8.0 (4.2)	6.7 (4.9)

The values are given as mean (SD).

Table 2 Mean (SD) percentage reduction of size of periapical lesion at time intervals postsurgery by experimental group

	Experimental group		
Time interval	Periosteal graft (n = 15)	Absorbable membrane (n = 15)	P-value[a]
3	59.5 (25.3)	41.5 (23.8)	0.059
6	78.4 (20.0)	76.9 (23.0)	0.92
9	87.8 (17.4)	85.5 (16.1)	0.46
12	91.1 (18.1)	87.0 (18.6)	0.24

[a]Mann–Whitney *U*-test.

Table 3 Results of combined clinical-radiographic healing 12 months postsurgery by experimental group

	Experimental group	
Radiographic healing	Periosteal graft (n = 15)	Absorbable membrane (n = 15)
Complete	9 (60)	6 (40)
Incomplete	4 (27)	7 (47)
Uncertain	2 (13)	0 (0)
Unsatisfactory	0 (0)	2 (13)

The values are given as n (%).

were classified as uncertain healing. These cases were regarded as intermediate between 'incomplete' and 'unsatisfactory' healing as although the rarefaction had decreased compared with the immediate postoperative radiograph, well-defined periradicular radiolucencies remained symmetrically placed around the root ends and some clinical signs and symptoms were still present. No subsequent failure was noted in any case that healed during the observation period.

Discussion

The occurrence of a periapical pathosis, accompanied by periodontal breakdown, constitutes a complex problem in periradicular surgery, typically associated with a less favourable prognosis, as disruption of the cortical plate can have a deleterious effect on the regeneration process of the lost tissues (Abramowitz *et al.* 1994, Jansson *et al.* 1997). With the introduction of GTR using membrane barriers, a new treatment modality has surfaced, which has been shown to be superior to the traditional technique of just repositioning the mucoperiosteal flap over the buccally exposed roots (Von Arx & Cochran 2001).

However, only partial information is available with regard to GTR therapy in periradicular surgery when the periodontal component is present. Although various case reports provide the main support for barrier techniques (Abramowitz *et al.* 1994, Rankow & Krasner 1996, Uchin 1996, Brugnami & Mellonig 1999, Tobón-Arroyave *et al.* 2004), without control lesions of similar pattern to evaluate healing and comparing different approach, conclusions can only be made cautiously (Von Arx & Cochran 2001). Few experimental studies (Douthitt *et al.* 2001) and controlled-clinical trials (Dietrich *et al.* 2003) have appeared in the literature that deals specifically with this issue. In those studies, the authors concluded that the application of GTR with an absorbable membrane enhances both the apical regeneration of bone and the regeneration of the connective tissue attachment and marginal alveolar bone on the buccal root surface.

In this study, using clinical, radiographic and digital analysis, the amount of healing of the bony defect appeared to be influenced by GTR techniques, as statistically significant reductions were seen in the PD, CAL and SPL. However, in studies on the regenerative potential of the four-walled bony defects confined only to the periapical area (Maguire *et al.* 1998, Garret *et al.* 2002), neither the rate nor the amount of healing of bony defect was influenced by the resorbable membrane. Unlike this study, those investigations had no a periodontal component to them. As the periosteum is not damaged in such cases, this enhances the likelihood of repair (Pecora *et al.* 2001) and the defects could have healed without the use of the membrane.

Although there is increasing evidence suggesting that GTR is because of guided cells that repopulate a previously diseased root surface, an aspect of great importance in the healing of periradicular surgery is the stabilization of the fragile root-clot interface (Douthitt *et al.* 2001). In this regard barriers may supply support to the replaced tissue and to play a significant role in preventing salivary and bacterial contamination or mechanical disruption of blood clots and their detachment from the root surface (Garret *et al.* 1988, Wikesjö *et al.* 1991). The coagulum stabilization may be responsible for preventing apical migration of the junctional epithelium, allowing undisturbed wound maturation and repair (Polson & Proye 1983, Douthitt *et al.* 2001). Resorbable barriers that are present during the early phases of wound repair may protect the fibrin clot from disruptive tensile forces. It may take 3–6 weeks before the root surface-gingival flap interface reaches sufficient maturity to withstand tissue manipulation (Polson & Proye 1983). In this study, periosteal grafts performed similarly to absorbable barriers regarding reduction of SPL and combined clinical-radiographic healing, thus suggesting they seem to be able to fulfil the requirements of wound stabilization.

The results in this study with the use of a periosteal sliding grafts are consistent with those described by Lekovic *et al.* (1991) and Kwan *et al.* (1998), who used free autogenous periosteal grafts for the treatment of furcation involvements and intrabony defects, and observed significant gains in clinical attachment and osseous defect fill. In all these situations the placement of the periosteum in direct contact with the root surface may modify the cellular dynamics of wound healing (Kerdvongbundit *et al.* 1999). According to Harrison & Jurosky (1992) there is an inductive influence from the new bone to the reforming periosteum to develop osteogenic potential and become a functioning periosteum at 14 days postsurgery. Furthermore, vascularized periosteum has the most significant osteogenic capacity at 2 weeks, with a constant level of activity maintained thereafter (Ishida *et al.* 1996). Thus, the periosteal grafts perform not only as barriers in preventing apical migration of the epithelium during the early phases of wound repair, but also contribute to new bone formation as time passes.

Based on practical aspects of the two surgical techniques, periosteal grafts have some therapeutic advantages over absorbable barriers, in that it can be easily harvested, are relatively abundant, healing of donor and recipient areas is well tolerated by patients (Kwan *et al.* 1998), the configuration of the graft can be adjusted to the shape of the recipient site (Ishida *et al.* 1996), better cost-effectiveness, and no patient morbidity by exposure. The only disadvantages are moderate degree of difficulty encountered when tissue is split, and increased surgical time.

Clinical evidence suggests that most changes between the various healing groups take place during the first postoperative year and that very few cases shift from one group to another on later follow-up examination (Skoglund & Persson 1985, Zuolo *et al.* 2000). In the present study, bony formation increased over time in both groups and it was evident that the success rate was higher than the overall rate observed after periradicular surgery in cases of severe bone dehiscence (Skoglund & Persson 1985, Jansson *et al.* 1997). The cases were classified as a success in the study after 1 year in the absence of clinical signs and symptoms and radiographic classification of complete and incomplete healing as suggested by Rud *et al.* (1972). On the contrary, the failure and uncertain healing rates in each group represented about 13% of the treated cases and compared favourably with previously reported failure rate in apicomarginal defects treated with bone grafting and GTR (Dietrich *et al.* 2003). The reasons for failures in the membrane group and uncertain healing in the periosteal graft group were not related to the surgical procedure itself, but might represent a more complex biological response involving various factors such as bacterial contamination on the external root surface (Ricucci *et al.* 2005), local site characteristics, and innate wound-healing potential (Cortellini & Tonetti 2000). Although the surgical procedure was repeated in those cases with unsatisfactory healing, the cause of failure could not be detected. All these patients continue to be monitored at 6-month intervals in order to detect any evidence of signs and/or symptoms of inflammation.

Several limitations were associated with the present study. First, the small sample size in association with the variability of bone defects might have influenced the results, as the size of these defects might not represent critical-size defects to evaluate the effects of GTR. In other words, not only the volume or height of the defect but also the shape of the defect and the amount of periodontal ligament tissue bordering the various walls of the defect may influence the amount of regeneration that can occur (Kerdvongbundit *et al.* 1999). A study with more patients would have greater statistical power and precision. Secondly, as biopsy material is difficult to obtain, for ethical reasons, the cited outcomes should be interpreted as evidence of improved healing response in the lack of histological evidence (Lindhe & Echeverria 1994). Hence histological analysis is essential to verify the efficacy of periosteal grafts and bioabsorbable barriers in promoting bone regeneration. Finally, all clinical measurements were performed by one examiner (JA) who was masked to the barrier technique used. Although this may have introduced bias because of different probing forces when the measurements were performed, inter-examiner reproducibility did not affect the comparison of the different barrier materials.

Conclusion

The results when considered within the limitations of this study indicate that the application of GTR to apicomarginal defects using sliding periosteal grafts are similar to bioabsorbable membranes for enhancing the clinical outcome of periradicular surgery in terms of periapical healing, gain of periodontal support, PD reduction and minimal recession of the gingival margin.

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References

Abramowitz PN, Rankow H, Trope M (1994) Multidisciplinary approach to apical surgery in conjunction with the loss of buccal cortical plate. *Oral Surgery Oral Medicine Oral Pathology* **77**, 502–6.

Baek S-H, Kim S (2001) Bone repair of experimentally induced through-and-through defects by Gore-Tex, Guidor, and Vicryl in ferrets: a pilot study. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics* **91**, 710–4.

Brugnami F, Mellonig JT (1999) Treatment of a large periapical lesion with loss of labial cortical plate using GTR: a case report. *International Journal of Periodontics and Restorative Dentistry* **19**, 243–9.

Chanavaz M (1995) Anatomy and histophysiology of the periosteum: quantification of the periosteal blood supply to the adjacent bone with 85Sr and gamma spectrometry. *Journal of Oral Implantology* **21**, 214–9.

Cortellini P, Tonetti MS (2000) Focus on intrabony defects: guided tissue regeneration. *Periodontology 2000* **22**, 104–32.

Dahlin C, Linde A, Gottlow J, Nyman S (1988) Healing of bone defects by guided tissue regeneration. *Plastic and Reconstuctive Surgery* **81**, 672–6.

Dietrich T, Zunker P, Dietrich D, Bernimoulin JP (2003) Periapical and periodontal healing after osseous grafting and guided tissue regeneration treatment of apicomarginal defects in periradicular surgery: results after 12 months. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics* **95**, 474–82.

Douthitt JC, Gutmann JL, Witherspoon DE (2001) Histologic assessment of healing after the use of a bioresorbable membrane in the management of buccal bone loss concomitant with periradicular surgery. *Journal of Endodontics* **27**, 404–10.

Eyre-Brook AL (1984) The Periosteum: its function reassessed. *Clinical Orthopedics and Related Research* **189**, 300–7.

Garret S, Loss B, Chamberlain D, Egelberg J (1988) Treatment of intraosseous periodontal defects with a combined adjunctive therapy of citric acid conditioning, bone grafting, and placement of collagenous membranes. *Journal of Clinical Periodontology* **15**, 383–9.

Garret K, Kerr M, Hartwell G, O'Sullivan S, Mayer P (2002) The effect of a bioresorbable matrix barrier in endodontic surgery on the rate of periapical healing: an *in vivo* study. *Journal of Endodontics* **28**, 503–6.

Goldman HM, Smukler H (1978) Controlled surgical stimulation of periosteum. *Journal of Periodontology* **49**, 518–22.

Gotfredsen K, Nimb L, Buser D, Hjørting-Hansen E (1993) Evaluation of guided bone regeneration around implants placed into fresh extraction sockets: an experimental study in dogs. *Journal of Oral and Maxillofacial Surgery* **51**, 879–84.

Gottlow J, Nyman S, Lindhe J, Karring T, Wennström J (1986) New attachment formation in the human periodontium by guided tissue regeneration. Case reports. *Journal of Clinical Periodontology* **13**, 604–16.

Gutmann JL, Harrison JW, ed. (1991) Success, failure, and prognosis in periradicular surgery. In: *Surgical Endodontics*, 1st edn. Boston, MA, USA: Blackwell Scientific Publications, pp. 338–84.

Harrison JW, Jurosky KA (1992) Wound healing in the tissues of the periodontum following periradicular surgery. III. The osseous excisional wound. *Journal of Endodontics* **18**, 76–81.

Hirsch JM, Ahlstrom U, Henrikson PA, Heyden G, Peterson LE (1979) Periapical surgery. *International Journal of Oral Surgery* **8**, 173–85.

Hollinger J, Wong MEK (1996) The integrated processes of hard tissue regeneration with special emphasis on fracture healing. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **82**, 594–606.

Hutmacher D, Hürzeler MB, Schliephake H (1996) A review of material properties of biodegradable and bioresorbable polymers and devices for GTR and GBR applications. *International Journal of Oral and Maxillofacial Implants* **11**, 667–78.

Ishida H, Tamai S, Yajima H, Inoue K, Ohgushi H, Dohi Y (1996) Histologic and biochemical analysis of osteogenic capacity of vascularized periosteum. *Plastic and Reconstructive Surgery* **97**, 512–8.

Jansson L, Sandstedt P, Låftman AC, Skoglund A (1997) Relationship between apical and marginal healing in periradicular surgery. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **83**, 596–601.

Kerdvongbundit V, Sirirat M, Sirikulsathean A (1999) A clinical comparison of the new attachment obtained by guided tissue regeneration and coronally positioned flap techniques in the management of human molar furcations defects. *Australian Dental Journal* **44**, 31–9.

Kwan SK, Lekovic V, Camargo PM et al. (1998) The use of autogenous periosteal grafts as barriers for the treatment of intrabony defects in humans. *Journal of Periodontology* **69**, 1203–9.

Lekovic V, Kenney EB, Carranza FA, Martignoni M (1991) The use of autogenous periosteal grafts as barriers for the treatment of class II furcation involvements in lower molars. *Journal of Periodontology* **62**, 775–80.

Lieblich SE (2002) Periapical surgery: clinical decision making. *Oral and Maxillofacial Surgery Clinics of North America* **14**, 179–86.

Lindhe J, Echeverria J (1994) Consensus report of session II. In: Lang N, Karring T, ed. *Proceedings on the 1st European Workshop on Periodontology*. London: Quintessence Publishing Co., pp. 210–4.

Maguire H, Torabinejad M, McKendry D, McMillan P, Simon J (1998) Effects of resorbable membrane placement and human osteogenic protein-1 on hard tissues healing after periradicular surgery in cats. *Journal of Endodontics* **24**, 720–5.

Newcombe RG (2006) Confidence intervals for an effect size measure based on the Mann–Whitney statistic 2. Asymptotic methods and evaluation. *Statistics in Medicine* (in press).

Nyman S (1991) Bone regeneration using the principle of guided tissue regeneration. *Journal of Clinical Periodontology* **18**, 494–8.

Nyman S, Lindhe J, Karring T, Rylander H (1982) New attachment following surgical treatment of human periodontal disease. *Journal of Clinical Periodontology* **9**, 290–6.

Oh TJ, Meraw SJ, Lee EJ, Giannobile WV, Wang HL (2003) Comparative analysis of collagen membranes for the treatment of implant dehiscence defects. *Clinical Oral Implants Research* **14**, 80–90.

Pecora G, De Leonardis D, Ibrahim N, Bovi M, Cornelini R (2001) The use of calcium sulphate in the surgical treatment of a 'through and through' periradicular lesion. *International Endodontic Journal* **34**, 189–97.

Polson AM, Proye MP (1983) Fibrin linkage. A precursor for new attachment. *Journal of Periodontology* **54**, 141–7.

Rankow H, Krasner P (1996) Endodontic applications of guided tissue regeneration in endodontic surgery. *Journal of Endodontics* **22**, 34–43.

Ricucci D, Martorano M, Bate AL, Pascon EA (2005) Calculus-like deposit on the apical external root surface of teeth with post-treatment apical periodontitis: report of two cases. *International Endodontic Journal* **38**, 262–71.

Rud J, Andreasen JO, Möller-Jensen JE (1972) Radiographic criteria for the assessment of healing after endodontic surgery. *International Journal of Oral Surgery* **1**, 195–214.

Schliephake H (2002) Bone growth factors in maxillofacial skeletal reconstruction. *International Journal of Oral and Maxillofacial Surgery* **31**, 469–84.

Skoglund A, Persson G (1985) A follow-up study of apicoectomized teeth with total loss of the buccal bone plate. *Oral Surgery, Oral Medicine and Oral Pathology* **59**, 78–81.

Tobón-Arroyave SI, Domínguez-Mejía JS, Flórez-Moreno GA (2004) Periosteal grafts as barriers in periradicular surgery: report of two cases. *International Endodontic Journal* **37**, 632–42.

Uchin RA (1996) Use of bioresorbable guided tissue membrane as an adjunct to bony regeneration in cases requiring endodontic surgical intervention. *Journal of Endodontics* **22**, 94–6.

Ueno T, Mizukawa N, Sugahara T (1999) Experimental study of bone formation from autogenous periosteal graft following insulin-like growth factor I administration. *Journal of Craniomaxillofacial Surgery* **27**, 308–13.

Ueno T, Kagawa T, Ishida N et al. (2001) Prefabricated bone graft induced from grafted periosteum for the repair of jaw defects: an experimental study in rabbits. *Journal of Craniomaxillofacial Surgery* **29**, 219–23.

Vandana KL, Vanda KV (2003) Periodontal regeneration in vital and nonvital teeth. A clincal study. *Endodontology* **15**, 26–32.

Von Arx T, Cochran DL (2001) Rationale for the application of the GTR principle using a barrier membrane in endodontic surgery: a proposal classification and literature review. *The International Journal of Periodontics and Restorative Dentistry* **21**, 127–39.

Wang HL, MacNeil RL (1998) Guided tissue regeneration: Absorbable barriers. *Dental Clinics of North America* **42**, 505–22.

Wikesjö UME, Claffey N, Egelberg J (1991) Periodontal treatment in dogs: effect of heparin treatment on the root surface. *Journal of Clinical Periodontology* **18**, 60–4.

Zuolo ML, Ferreira MOF, Gutmann JL (2000) Prognosis in periradicular surgery: a clinical prospective study. *International Endodontic Journal* **33**, 91–8.