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Changes of periodontal parameters following apical surgery: a prospective clinical study of three incision techniques

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Abstract

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Aim To evaluate periodontal changes following apical surgery, and to relate changes to the type of incision and to the type of restoration present at the gingival margin (GM).

Methodology Periodontal parameters [probing depth (PD), level of GM and clinical attachment, plaque and bleeding indices] were recorded at baseline and 1 year following apical surgery. The periodontal changes were calculated and assessed with respect to the incision technique (intrasulcular incision, papilla base incision and submarginal incision), as well as to the presence and type of a restoration margin in contact with the gingiva.

Results One hundred and eighty-four teeth could be evaluated. No significant differences between the three incision techniques were found regarding changes in PDs and plaque index over time. However, significant differences between the intrasulcular and submarginal incisions were found for changes in levels of GM and clinical attachment. For example, with the intrasulcular incision, there was a mean recession of 0.42 mm at buccal sites, whereas using the submarginal incision there was a gain of 0.05 mm. No statistically significant influence could be demonstrated for the presence and type of restoration margins, or the smoking habit of the patient.

Conclusion The type of incision was found to affect changes significantly in periodontal parameters within an observation period of 1 year following apical surgery, whereas the restoration margin and smoking habit did not prove to have any significant effect.

Keywords: apical surgery, incision technique, periodontal changes, restoration margin.

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Introduction

One of the main objectives of apical surgery following root-end resection is to seal the root canal system, thereby enabling healing by forming a barrier between the irritants within the confines of the affected root and the tissues surrounding the root (von Arx 2005). This seal is usually accomplished by root-end cavity preparation, with subsequent root-end filling. Initially, a flap must be raised to gain access to the root end; this is followed by exposure and removal of the bone covering the lesion and root tip. The incision and flap design is one of the important steps in apical surgery and a number of criteria must be considered when choosing the type and outline of the flap: location and extension of the apical lesion, periodontal condition of affected and adjacent teeth, adjacent anatomical structures, and presence and quality of restoration margins (Velvart & Peters 2005).

Few animal and clinical studies have examined soft tissue healing in relation to apical surgery. Kramper *et al.* (1984) evaluated three flap designs in beagle

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dogs at intervals of up to 60 days. Inflammatory changes persisted longer in the semilunar (alveolar mucosa) and intrasulcular incisions compared with submarginal incisions, and these changes delayed healing of the wound. Loss of alveolar bone occurred with the intrasulcular incision. Visible scarring was observed in the submarginal and semilunar incisions.

Harrison & Jurosky (1991) compared the wound healing of an intrasulcular triangular flap and a submarginal rectangular flap following apical surgery in rhesus monkeys. Little difference was found in the temporal and qualitative healing responses with the two flap designs. Vital connective tissue and epithelium, although not visible clinically, remained attached to the root surfaces following reflection of the intrasulcular incision flap. Preservation of these tissues prevented apical epithelial downgrowth and loss of attachment. Incisional wounds of both flaps showed epithelial barrier formation within 3 days.

Selvig & Torabinejad (1996) evaluated wound healing after mucogingival flap surgery that included an intrasulcular incision in cats. They reported that the incision had severed the dentogingival fibres at a distance of 0.2–0.5 mm from the root surface, and in no instance had the cementum surface been completely denuded. The fastest healing was observed in the region of the free gingiva (7 days), whereas healing of the attached gingiva (14 days) and of the alveolar mucosa (28 days) took considerably longer.

In a clinical study with 59 patients, Jansson *et al.* (1997) evaluated the relationship between apical and marginal (periodontal) healing following apical surgery. Periodontal attachment and pocket depth of teeth undergoing surgery, and of control teeth, were assessed at the time of surgery and 1 year after surgery. The clinical attachment level (CAL) decreased by 0.26 mm for root-end resected teeth compared to 0.07 mm for contralateral control teeth ($P < 0.05$). The mean loss of CAL for root-end resected teeth with unsuccessful healing (0.85 mm) also differed significantly ($P = 0.04$) from successfully healed teeth (0.15 mm).

Velvart *et al.* (2004) assessed the papilla height following apical surgery over a period of 1 year in 12 patients. The flap design consisted of two releasing incisions and complete mobilization of one papilla using an intrasulcular incision, whereas the other papilla was maintained using a so-called papilla base incision (PBI). After 1 year, a loss of papilla height of 0.98 mm was observed for the intrasulcular incision, whereas no loss of papilla height (−0.06 mm) was found for PBI ($P < 0.001$).

The objective of this clinical study was to collect periodontal data pre-operatively and 1 year after apical surgery, and to relate changes to the incision design and to the type of restoration present at the gingival margin (GM).

Material and methods

Patient selection

Patients with 238 teeth undergoing apical surgery were consecutively enrolled from 2000 to 2004. Patients were fully instructed about the surgical procedure, post-operative care, follow-up examinations and alternative treatment options. Each patient signed a consent form according to the Declaration of Helsinki.

Surgical technique

Apical surgery was performed under local anaesthesia (articaine 4% with 1 : 100 000 epinephrine) in an operating room. Following the elevation of a full-thickness mucoperiosteal flap, osteotomy was carried out with round burs under copious saline irrigation. Affected roots were then resected approximately 3 mm from the apex. Following debridement of the pathological tissue, haemostasis of the bony crypt was achieved with aluminium-chloride (Expasyl, Produits Dentaires Pierre Rolland, Merignac, France) and/or ferric sulphate (Stasis, Belport Co, Camarillo, CA, USA). Caution was exercised to avoid contamination of the marginal periodontium with the haemostatic agents. After staining the surgical area with methylene blue, the root end was inspected for the presence of fractures, cracks or isthmuses using a rigid endoscope (von Arx *et al.* 2002). Root-end cavities were prepared with sonic-driven microtips (von Arx & Kurt 1999), and were either filled with SuperEBA (Staident International, Staines, UK), or with MTA (Mineral Trioxide Aggregate, Dentsply Tulsa Dental, Tulsa, OK, USA). Alternatively, a shallow concavity was prepared into the cut root face using round diamond burs, with subsequent placement of dentine-bonded resin composite (Retroplast, Retroplast Trading, Rorvig, Denmark) (Rud *et al.* 1996). After cleaning the wound area, primary wound closure

was accomplished with multiple interrupted sutures. Surgeries and data collection were performed by one of the authors (T.v.A.).

Medication

All patients were given nonsteroidal analgesics, and patients were instructed to rinse their mouth twice daily with 0.1% chlorhexidine-digluconate for 10 days. Antibiotics were not prescribed routinely. When antibiotics were given, they included 2-g amoxicillin-clavulanic acid, or alternatively, 600-mg clindamycin, to be taken 2 h pre-operatively.

Follow-up

Patients were seen 4–7 days after surgery for suture removal. All patients were recalled 1 year after periapical surgery for the follow-up examination.

Evaluation parameters

Pre-operatively and 1 year after surgery, the following periodontal data were collected at mesio-buccal, mid-buccal, disto-buccal and lingual sites of the teeth undergoing apical surgery. Measurements at the mesio-buccal and disto-buccal sites were taken at the buccal line angles of the tooth.

1. Probing depth (PD): a periodontal probe (Colorvue Tip, Hu-Friedy, Leimen, Germany) was used to measure the PD to the nearest 0.5 mm.

2. Level of GM: utilizing the same probe, the distance from the GM to the cemento-enamel junction (CEJ) or to the apical margin of a present restoration was measured to the nearest 0.5 mm (negative values for sites with exposed root surface).

3. CAL: these values were calculated by subtracting GM values from PD values (CAL = PD − GM).

4. Plaque index (PLI): the modified PLI according to Mombelli *et al.* (1987) was used: score 0 = no plaque, score 1 = plaque only detected with probe, score 2 = plaque visible by naked eye, score 3 = abundant plaque.

5. Bleeding index (BI): the modified BI according to Mombelli *et al.* (1987) was used: score 0 = no bleeding, score 1 = isolated bleeding spots, score 2 = confluent blood line, score 3 = profuse bleeding.

In addition, the presence and type of a restoration margin in contact with the labial/buccal gingiva was noted (no restoration, filling margin and crown margin). The smoking habit (yes or no) was also recorded.

With respect to the type of incision, three incision techniques were evaluated:

1. Intrasulcular incision (Fig. 1): using a 15C blade (Swann-Morton, Sheffield, UK), this incision was made through the sulcus of the affected tooth and both adjacent teeth. A mesial release incision was made starting from the mesial line angle of the tooth anterior to the tooth to be resected. Distal release incisions were only used in molars requiring apical surgery of distal roots.

2. PBI (Fig. 2): in the region of both adjacent papillae, the incision line continued through the papilla base in a curvilinear fashion, whereas on the facial aspect of the tooth, the incision was placed intrasulcularly. Again, a mesial release incision was made starting from the mesial line angle of the adjacent tooth.

3. Submarginal incision (Fig. 3): this incision was placed within the attached gingiva, extending to both adjacent teeth in a scalloped fashion. A release incision was made at the mesial end of the scalloped incision.

No randomization was used for choosing a specific incision technique. The submarginal incision was mainly used in the maxillary aesthetic zone, provided the attached gingiva had sufficient width. For posterior sites, the intrasulcular incision was the preferred incision technique. Alternatively, the recently introduced PBI was used in posterior sites. The PBI was further used in the maxillary aesthetic zone with an insufficient width of attached gingiva.

Inclusion and exclusion criteria

To be included in this study, access to the lesion had to be gained from the buccal aspect. Teeth with palatal access to palatal roots were excluded ($n = 7$). In addition, 19 teeth presenting with apico-marginal defects were also excluded. In 12 patients, multiple (adjacent) teeth ($n = 27$) were treated. These teeth were also disqualified for this analysis to avoid the intra-individual influence and the interference of teeth treated adjacent to each other (Table 1).

Statistics

Data were prepared and evaluated using SAS® Statistical Analysis System (SAS Institute Inc., Cary, NC, USA; SAS Institute Inc. 1999). Paired differences in time (follow-up value minus baseline value) on a single tooth (Table 2) were calculated and tested on significances using the Wilcoxon-Matched-Pairs Signed Rank

Figure 1 (a) Schematic illustration of intrasulcular incision. (b) Baseline situation before apical surgery of mandibular left first premolar. (c) Intra-operative view following re-adaptation of wound margins. (d) One-year follow-up: note recession of buccal gingiva and distal papilla.

Test (SAS® PROC Univariate). Influences of incision technique (Table 3), restoration margin (Table 4) and tooth (Table 5) on changes over time were assessed with the Mann–Whitney *U*-test (SAS® PROC NPAR1-WAY).

Results

One hundred and eighty-five teeth met the inclusion criteria; one tooth was lost as the patient did not attend for the 1-year follow-up. The majority of treated teeth included mandibular molars ($n = 55$) and anterior maxillary teeth ($n = 50$) (Table 6). In this study, 131 individuals were nonsmokers (71%).

Baseline and follow-up measurements of the evaluated periodontal parameters for all teeth and sites are shown in Table 2. With regard to measurements of PD, GM and CAL, changes over time were greater at buccal sites compared with lingual sites. For instance, the mean recession shown by GM amounted to 0.32 mm for pooled buccal sites compared to 0.16 mm for lingual sites.

The distribution of teeth per incision technique is shown in Table 7. The submarginal incision was mainly used in maxillary anterior teeth (78.8%), whereas the intrasulcular incision and the PBI were both most often applied in mandibular molars. The changes of periodontal parameters with respect to evaluated sites and incision techniques are listed in Table 3. No significant differences were found for changes of PDs and PLI over time when the three incision techniques were compared. However, significant differences were seen for changes of GM and CAL in all sites when the intrasulcular incision was compared with the submarginal incision. For example, the intrasulcular incision led to a mean recession of 0.42 mm for the pooled buccal sites whereas the submarginal incision led to a gain of 0.05 mm. Similarly, the individual buccal sites showed more gingival recession for the intrasulcular incision

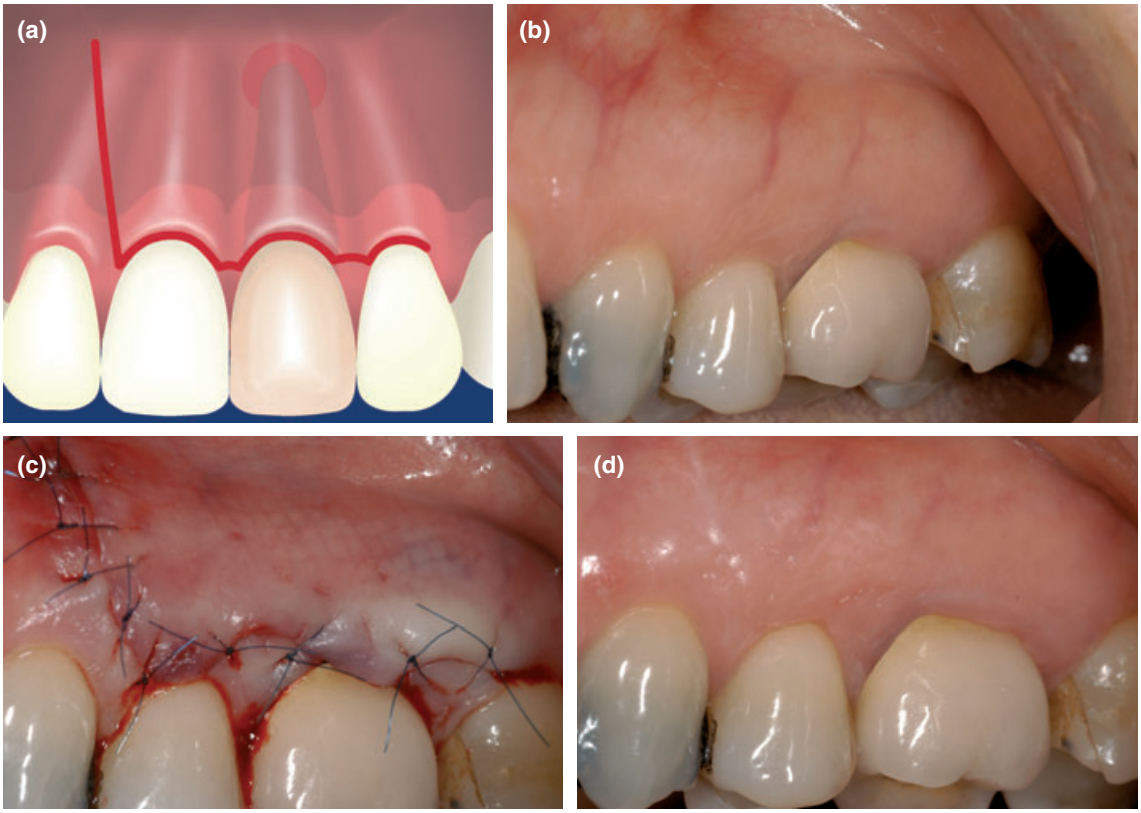

Figure 2 (a) Schematic illustration of papilla base incision. (b) Baseline situation before apical surgery of maxillary left first molar. (c) Intra-operative view following re-adaptation of wound margins. (d) One-year follow-up: note stable gingival and papillary tissues.

compared with the submarginal incision. Analogous findings were noted for the CAL, with attachment loss for the intrasulcular incision but attachment gain for the submarginal incision. When the PBI was compared to the submarginal incision as well as to the intrasulcular incision, only selected sites showed significant differences for GM and CAL (Table 3).

The distribution of teeth per restoration margin is shown in Table 8. For the most part, no restoration margin was seen in maxillary molars (42.9%), whereas the highest frequency of crown margins was seen in mandibular molars (35.1%). With regard to the type of restoration margin, only one data comparison proved significant: the change of PD at the mid-buccal site.

Comparing the different tooth groups, significantly more attachment loss was noted at mid-buccal sites for mandibular premolars compared with maxillary anterior teeth and mandibular molars (Table 5). In contrast, changes of CAL at all other sites across the various tooth groups were not significantly different.

No significant differences were observed for the evaluated periodontal parameters when smokers were compared with nonsmokers.

Discussion

This clinical study evaluated the changes of periodontal parameters following apical surgery with an observation period of 1 year. In addition, the changes were assessed according to the type of incision used for flap elevation, the type of restoration margin and the smoking habit of the patient. With only one patient out of 185 not attending for the 1-year follow-up, the drop-out rate was low.

With regard to the evaluated incision techniques, the intrasulcular incision demonstrated the greatest changes of GM and CAL, meaning more recession of the GM and more loss of attachment compared with the other incision techniques. One could argue that the intrasulcular incision was mainly used in periodontally

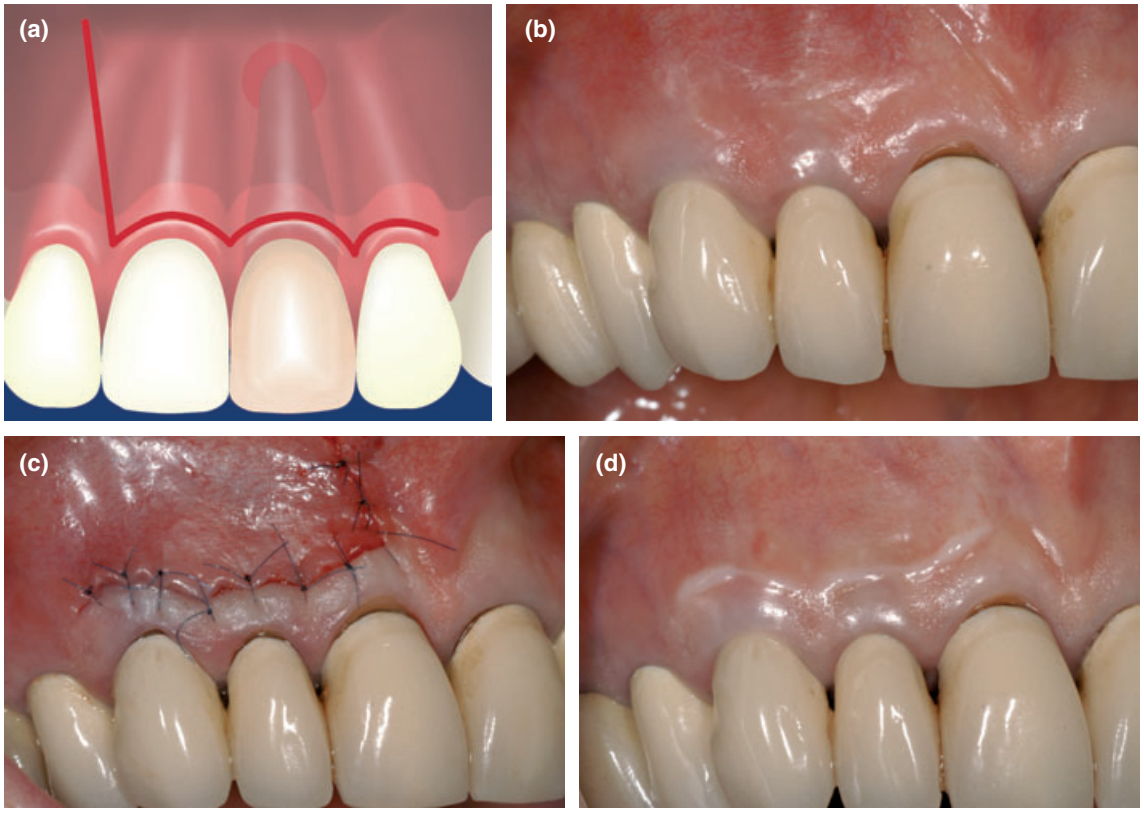

Figure 3 (a) Schematic illustration of submarginal incision. (b) Baseline situation before apical surgery of maxillary right lateral incisor. (c) Intra-operative view following re-adaptation of wound margins. (d) One-year follow-up: note stable gingival contour but scar tissue formation along former incision line.

Table 1 Flow-chart of treated cases

Number of teeth		Numbers excluded	Reason for exclusion
238	Initial number of treated teeth		
⇓		7	Palatal access
231			
⇓		19	Apico-marginal lesions
212			
⇓		27	Multiple (adjacent) teeth treated in same patient
185			
⇓		1	Drop-outs (patients did not show up for 1-year control)
184	Final number of evaluated teeth		

compromised teeth. However, PDs at baseline did not differ significantly across the three incision groups (data not shown). Another reason explaining more recession and attachment loss for the intrasulcular incision might be excessive forces to the marginal tissues during flap elevation, exposure of marginal (bone) tissues for 45–90 min with possible tissue dehydration, and bone remodelling during healing (Levin *et al.* 1977, Harrison & Jurosky 1991).

With regard to the incision, the use of microblades (width not exceeding 2.5 mm) has been recommended (Velvart & Peters 2005). Suitable shapes recommended by these authors are blades with rounded ends or standard 15C blades. However, no studies are available

Table 2 Periodontal parameters (mean ± SD) per site and time-point of examination for all teeth ($n = 184$)

Site	Time-point	PD (±SD)	GM (±SD)	CAL (±SD)	PLI (±SD)	BI (±SD)
Mesio-buccal	Baseline	2.60 (±0.54)	0.32 (±0.93)	2.28 (±0.93)	0.23 (±0.54)	0.38 (±0.67)
	1-year follow-up	2.51 (±0.49)	0.04 (±0.93)	2.46 (±0.84)	0.18 (±0.52)	0.26 (±0.54)
	Change	−0.10 (±0.54)*	−0.28 (±0.82)*	0.18 (±0.86)*	−0.05 (±0.54)	−0.11 (±0.71)*
Mid-buccal	Baseline	2.46 (±0.63)	−0.19 (±0.92)	2.65 (±1.02)	0.14 (±0.45)	0.23 (±0.55)
	1-year follow-up	2.39 (±0.61)	−0.51 (±0.97)	2.90 (±1.00)	0.10 (±0.40)	0.16 (±0.43)
	Change	−0.07 (±0.55)	−0.32 (±0.77)*	0.25 (±0.89)*	−0.03 (±0.43)	−0.08 (±0.61)
Disto-buccal	Baseline	2.88 (±0.83)	0.46 (±1.04)	2.42 (±1.05)	0.28 (±0.62)	0.78 (±0.96)
	1-year follow-up	2.69 (±0.65)	0.12 (±0.96)	2.57 (±0.94)	0.21 (±0.53)	0.35 (±0.65)
	Change	−0.19 (±0.79)*	−0.35 (±0.90)*	0.15 (±0.89)*	−0.07 (±0.64)	−0.43 (±0.96)*
Pooled buccal	Baseline	2.65 (±0.51)	0.20 (±0.83)	2.45 (±0.85)	0.22 (±0.43)	0.46 (±0.49)
	1-year follow-up	2.53 (±0.45)	−0.12 (±0.83)	2.65 (±0.79)	0.16 (±0.41)	0.26 (±0.36)
	Change	−0.12 (±0.46)*	−0.32 (±0.66)*	0.20 (±0.68)*	−0.05 (±0.40)*	−0.21 (±0.49)*
Mid-lingual	Baseline	2.60 (±0.64)	0.06 (±0.86)	2.54 (±0.94)	0.56 (±0.73)	0.55 (±0.69)
	1-year follow-up	2.55 (±0.55)	−0.10 (±0.93)	2.65 (±0.96)	0.58 (±0.70)	0.42 (±0.63)
	Change	−0.05 (±0.54)	−0.16 (±0.77)*	0.11 (±0.87)	0.02 (±0.73)	−0.13 (±0.76)*

PD, probing depth; GM, level of gingival margin; CAL, clinical attachment level; PLI, plaque index; BI, bleeding index. *$P < 0.05$.

Table 3 Changes (mean ± SD) of periodontal parameters with respect to sites and incision techniques ($n = 184$)

Site	Incision technique	PD	GM	CAL*	PLI	BI
Mesio-buccal	Intrasulcular incision	−0.11 (±0. 58)	−0.41 (±0.81)^{x}	0.30 (±0.86)^{x}	−0.08 (±0.54)	−0.11 (±0.73)
	Papilla base incision	−0.09 (±0.44)	−0.27 (±0.69)$^{\circ}$	0.18 (±0.73)	0.06 (±0.43)	−0.24 (±0.66)
	Submarginal incision	−0.08 (±0.47)	0.15 (±0.81)$^{x\circ}$	−0.23 (±0.91)^{x}	−0.06 (±0.61)	0.00 (±0.71)
Mid-buccal	Intrasulcular incision	0.00 (±0.56)	−0.38 (±0.80)^{x}	0.38 (±0.91)^{x}	−0.05 (±0.43)	−0.14 (±0.63)
	Papilla base incision	−0.18 (±0.45)	−0.32 (±0.69)	0.14 (±0.92)	0.09 (±0.29)	0.00 (±0.43)
	Submarginal incision	−0.21 (±0.56)	−0.11 (±0.70)^{x}	−0.11 (±0.72)^{x}	−0.09 (±0.52)	0.09 (±0.68)
Disto-buccal	Intrasulcular incision	−0.13 (±0.88)	−0.47 (±0.98)^{x}	0.34 (±0.96)$^{x\Delta}$	−0.12 (±0.71)	−0.61 (±1.00)$^{x\Delta}$
	Papilla base incision	−0.35 (±0.55)	−0.33 (±0.55)$^{\circ}$	−0.02 (±0.62)$^{\Delta\circ}$	−0.06 (±0.56)	−0.27 (±0.80)$^{\Delta}$
	Submarginal incision	−0.26 (±0.59)	0.09 (±0.71)$^{x\circ}$	−0.35 (±0.57)$^{x\circ}$	0.09 (±0.46)	0.03 (±0.77)^{x}
Pooled buccal	Intrasulcular incision	−0.08 (±0.50)	−0.42 (±0.69)^{x}	0.34 (±0.68)$^{x\Delta}$	−0.08 (±0.42)	−0.29 (±0.48)^{x}
	Papilla base incision	−0.21 (±0.38)	−0.31 (±0.49)	0.10 (±0.62)$^{\Delta}$	0.03 (±0.33)	−0.17 (±0.43)
	Submarginal incision	−0.18 (±0.37)	0.05 (±0.61)^{x}	−0.23 (±0.57)^{x}	−0.02 (±0.38)	0.04 (±0.48)^{x}
Mid-lingual	Intrasulcular incision	−0.07 (±0.58)	−0.31 (±0.83)$^{x\Delta}$	0.24 (±0.93)^{x}	0.03 (±0.76)	−0.25 (±0.74)$^{x\Delta}$
	Papilla base incision	0.00 (±0.40)	0.06 (±0.63)$^{\Delta}$	−0.06 (±0.72)	−0.06 (±0.70)	0.09 (±0.77)$^{\Delta}$
	Submarginal incision	−0.05 (±0.54)	0.14 (±0.52)^{x}	−0.18 (±0.71)^{x}	0.06 (±0.66)	0.06 (±0.79)^{x}

PD, probing depth; GM, level of gingival margin; CAL, clinical attachment level; PLI, plaque index; BI, bleeding index.
*CAL: positive values = attachment loss; negative values = attachment gain.
$^{\Delta}$Statistics = significant differences between intrasulcular and papilla base incision.
^{x}Significant differences between intrasulcular and submarginal incision.
$^{\circ}$Significant differences between papilla base and submarginal incision.

that have evaluated the effect of different types of blades upon soft tissue healing following apical surgery. With respect to flap elevation, it is important to eliminate reflective forces to the marginal tissues by mobilization of the flap using a lateral approach from the vertical release incision (Harrison & Jurosky 1991). Experimental studies in animals have shown that up to one millimetre of buccal bone tissue is lost following flap elevation with (Cummings & Torabinejad 2000) or without (Kramper *et al.* 1984) apical surgery. In this study, no attempts were made to evaluate changes of the marginal bone levels following apical surgery. Another reason for increased recession might be the application of the haemostatic agents with contamination and damage to the marginal bone and periodontium. Any potentially toxic haemostatic agent should only be placed into the bony crypt that needs to be curetted or freshened using rotary instruments before wound closure (von Arx *et al.* 2006).

Interestingly, the intrasulcular incision was associated with a recession of the lingual gingival tissues and lingual attachment loss, although flaps were only raised on buccal aspects. No obvious reasons were found to explain these changes at lingual sites. In

Table 4 Changes (mean ± SD) of periodontal parameters with respect to sites and restoration ($n = 184$)

Site	Restoration margin	PD	GM	CAL*	PLI	BI
Mesio-buccal	No restoration	−0.25 (±0.58)	−0.25 (±0.75)	0.00 (±0.88)	−0.07 (±0.47)	−0.14 (±0.66)
	Filling	0.01 (±0.55)	−0.22 (±0.91)	0.24 (±0.87)	−0.08 (±0.73)	−0.14 (±0.68)
	Crown	−0.11 (±0.53)	−0.30 (±0.80)	0.19 (±0.86)	−0.04 (±0.48)	−0.10 (±0.73)
Mid-buccal	No restoration	0.07 (±0.65)	−0.29 (±0.58)	0.36 (±0.82)	−0.14 (±0.53)	−0.36 (±0.63)
	Filling	0.10 (±0.56)°	−0.19 (±0.90)	0.29 (±1.15)	−0.08 (±0.60)	−0.06 (±0.41)
	Crown	−0.13 (±0.52)°	−0.36 (±0.75)	0.23 (±0.83)	−0.01 (±0.36)	−0.05 (±0.65)
Disto-buccal	No restoration	−0.32 (±0.70)	−0.18 (±0.87)	−0.14 (±0.86)	−0.14 (±0.53)	−0.43 (±1.02)
	Filling	−0.26 (±0.75)	−0.21 (±0.98)	−0.06 (±0.92)	−0.14 (±0.64)	−0.42 (±1.05)
	Crown	−0.16 (±0.81)	−0.40 (±0.88)	0.24 (±0.87)	−0.04 (±0.66)	−0.44 (±0.94)
Pooled buccal	No restoration	−0.17 (±0.53)	−0.24 (±0.55)	0.07 (±0.58)	−0.12 (±0.46)	−0.31 (±0.44)
	Filling	−0.05 (±0.47)	−0.21 (±0.77)	0.16 (±0.83)	−0.10 (±0.50)	−0.20 (±0.49)
	Crown	−0.13 (±0.45)	−0.35 (±0.64)	0.22 (±0.66)	−0.03 (±0.36)	−0.20 (±0.49)
Mid-lingual	No restoration	−0.21 (±0.58)	−0.21 (±0.73)	0.00 (±1.13)	−0.14 (±0.66)	−0.36 (±0.93)
	Filling	−0.06 (±0.57)	−0.19 (±0.78)	0.14 (±0.93)	0.06 (±0.63)	−0.17 (±0.61)
	Crown	−0.03 (±0.53)	−0.15 (±0.78)	0.12 (±0.83)	0.02 (±0.76)	−0.10 (±0.78)

PD, probing depth; GM, level of gingival margin; CAL, clinical attachment level; PLI, plaque index; BI, bleeding index.
*CAL: positive values = attachment loss; negative values = attachment gain.
°Statistics = significant differences between filling margin and crown margin.

contrast, the lingual GM and CAL measurements remained stable for the PBI, or even improved slightly for the submarginal incision.

The mean loss of 0.34 mm of clinical attachment found in this study for pooled buccal sites following an intrasulcular incision was corroborated in a similar clinical study (Jansson *et al.* 1997) in which pooled buccal sites demonstrated a mean loss of 0.26 mm of clinical attachment after a healing period of 11–16 months. Interestingly, in both studies, PDs remained nearly unchanged (−0.08 mm in both studies), meaning that the buccal gingival tissues had receded (−0.42 mm vs. −0.34 mm). Jansson *et al.* (1997) also demonstrated that contra-lateral teeth presented no gingival recession with only a minimal change of CAL (0.07 mm). In this study, contra-lateral teeth were not evaluated.

With respect to the so-called PBI, few data are available. One clinical study (Velvart *et al.* 2004) evaluated papilla maintenance, comparing no mobilization of the papilla (PBI) to a complete mobilization of the entire papilla (intrasulcular incision). The study, however, did not report about (mid-)buccal changes of GM, PD and CAL. The tooth to be treated served as its own control, as the two different incision techniques were randomly assigned to either papilla. At the 1-year follow-up, the PBI showed no papilla shrinkage, compared with shrinkage of 0.98 mm for completely mobilized papillae ($P < 0.001$). The authors suggested the following reasons for papilla shrinkage seen with the intrasulcular incision: dimension of papilla (narrow-long papilla versus wide-short papilla), damage to papilla during elevation process and insufficient adaptation of papilla at flap closure. In this study, changes of the papilla height were not evaluated. However, the assessment of GM and CAL yielded smaller (=better) changes for the PBI compared with the intrasulcular incision, although significant differences were only found for CAL at disto-buccal and pooled buccal sites, as well as for GM at mid-lingual sites.

With regard to the submarginal incision, no clinical data have been reported in the literature. However, two animal studies have evaluated the submarginal incision. One study in dogs (Kramper *et al.* 1984) compared a submarginal incision (scalloped incision in the attached gingiva with two vertical release incisions) to an intrasulcular incision with two vertical release incisions, and to a semilunar incision in the alveolar mucosa. Healing periods ranged from 2 to 60 days. Except for scarring, the submarginal incision was found to be superior to the other two incision techniques with respect to clinical features (redness and swelling, epithelial closure and gingival recession) and histological features (degree of oedema and inflammation, connective tissue repair and epithelial closure). In contrast, another study in monkeys reported little difference in the temporal and qualitative healing responses to incisional wounds when a submarginal incision with two vertical release incisions was compared with an intrasulcular incision with a single vertical release incision (Harrison & Jurosky 1991).

Table 5 Changes (mean ± SD) of periodontal parameters with respect to sites and teeth ($n = 184$)

Site	Tooth group	PD	GM	CAL[#]	PLI	BI
Mesio-buccal	Max anterior	−0.15 (±0.48)	−0.24 (±0.92)	0.09 (±0.91)	−0.14 (±0.61)[x]	−0.12 (±0.59)
	Max premolars	0.03 (±0.60)	−0.43 (±0.91)	0.47 (±1.02)	−0.03 (±0.43)[Δ]	−0.03 (±0.82)
	Max molars	−0.15 (±0.63)	−0.23 (±0.82)	0.08 (±0.75)	0.04 (±0.55)	−0.29 (±0.62)
	Mand anterior	−0.25 (±0.65)	−0.75 (±0.87)	0.50 (±0.82)	−0.25 (±0.50)	0.00 (±1.63)
	Mand premolars	−0.12 (±0.42)	0.00 (±0.76)	−0.12 (±0.65)	0.31 (±0.48)[xΔ°]	−0.23 (±0.83)
	Mand molars	−0.11 (±0.52)	−0.27 (±0.64)	0.16 (±0.78)	−0.09 (±0.52)[°]	−0.07 (±0.66)
Mid-buccal	Max anterior	−0.17 (±0.49)[x]	−0.26 (±0.79)	0.09 (±0.88)[x]	−0.16 (±0.62)[x]	−0.08 (±0.78)
	Max premolars	−0.04 (±0.50)	−0.41 (±0.72)	0.37 (±0.91)	−0.03 (±0.16)[Δ]	−0.11 (±0.65)
	Max molars	−0.04 (±0.71)	−0.29 (±0.88)	0.25 (±1.07)	0.04 (±0.36)	0.08 (±0.58)
	Mand anterior	−0.25 (±0.65)	−0.88 (±0.75)	0.63 (±0.48)	0.00 (±0.00)	0.00 (±0.00)
	Mand premolars	0.15 (±0.47)[x]	−0.54 (±0.52)	0.69 (±0.78)[x°]	0.23 (±0.44)[xΔ°]	−0.23 (±0.60)
	Mand molars	−0.05 (±0.56)	−0.24 (±0.78)	0.18 (±0.84)[°]	−0.02 (±0.36)[°]	−0.09 (±0.44)
Disto-buccal	Max anterior	−0.27 (±0.70)	−0.30 (±1.01)	0.03 (±0.80)	−0.06 (±0.79)	−0.18 (±0.94)
	Max premolars	−0.15 (±0.68)	−0.50 (±0.66)	0.35 (±0.83)	−0.13 (±0.62)	−0.47 (±0.92)
	Max molars	−0.27 (±0.91)	−0.25 (±0.88)	−0.02 (±0.85)	−0.08 (±0.65)	−0.67 (±1.24)
	Mand anterior	−0.50 (±0.41)	−0.00 (±0.82)	−0.50 (±1.08)	0.00 (±0.00)	−0.75 (±0.96)
	Mand premolars	−0.12 (±0.96)	−0.62 (±1.10)	0.50 (±0.84)	0.08 (±0.64)	−0.54 (±0.88)
	Mand molars	−0.11 (±0.86)	−0.28 (±0.90)	0.17 (±0.99)	−0.07 (±0.54)	−0.49 (±0.88)
Pooled buccal	Max anterior	−0.20 (±0.39)[x]	−0.27 (±0.79)	0.07 (±0.71)	−0.12 (±0.48)	−0.13 (±0.53)
	Max premolars	−0.05 (±0.45)	−0.45 (±0.65)	0.39 (±0.74)	−0.06 (±0.30)	−0.20 (±0.44)
	Max molars	−0.15 (±0.59)	−0.26 (±0.70)	0.10 (±0.71)	0.00 (±0.41)	−0.29 (±0.55)
	Mand anterior	−0.33 (±0.50)	−0.54 (±0.63)	0.21 (±0.67)	−0.08 (±0.17)	−0.25 (±0.83)
	Mand premolars	−0.03 (±0.43)[x]	−0.38 (±0.66)	0.36 (±0.60)	0.21 (±0.46)	−0.33 (±0.53)
	Mand molars	−0.09 (±0.46)	−0.26 (±0.54)	0.17 (±0.62)	−0.06 (±0.34)	−0.22 (±0.41)
Mid-lingual	Max anterior	−0.02 (±0.48)	−0.14 (±0.80)	0.12 (±0.88)	0.14 (±0.67)	0.02 (±0.74)*
	Max premolars	0.03 (±0.56)	−0.11 (±0.57)	0.14 (±0.58)	−0.11 (±0.83)	−0.08 (±0.85)
	Max molars	−0.21 (±0.57)	−0.13 (±0.56)	−0.08 (±0.86)	0.00 (±0.72)	−0.25 (±0.85)
	Mand anterior	0.13 (±0.25)	0.00 (±0.00)	0.13 (±0.25)	−0.25 (±0.50)	−0.25 (±0.50)
	Mand premolars	−0.12 (±0.68)	−0.27 (±1.03)	0.15 (±1.21)	0.00 (±0.71)	0.08 (±0.76)
	Mand molars	−0.06 (±0.54)	−0.23 (±0.91)	0.16 (±0.87)	0.02 (±0.73)	−0.29 (±0.68)*

Max, maxillary; mand, mandibular; PD, probing depth; GM, level of gingival margin; CAL, clinical attachment level; PLI, plaque index; BI, bleeding index.
[#]CAL: positive values = attachment loss; negative values = attachment gain.
[x]Statistics = significant differences between maxillary anterior teeth and mandibular premolars.
[Δ]Significant differences between maxillary premolars and mandibular premolars.
[°]Significant differences between mandibular premolars and mandibular molars.
*Significant differences between maxillary anterior teeth and mandibular molars.

Table 6 Distribution of treated teeth ($n = 184$)

Teeth	*n*	%
Maxillary anterior	50	27.2
Maxillary premolars	38	20.7
Maxillary molars	24	13.0
Mandibular anterior	4	2.2
Mandibular premolars	13	7.1
Mandibular molars	55	29.9
Total	184	100

From a clinical perspective, the submarginal incision demonstrated the least (=best results) changes for GM and CAL in this study. In the aesthetic zone of the maxilla, this incision technique should be considered for apical surgery to avoid gingival recession. However, a careful evaluation of the dimensions of the labial soft tissues (width of free and attached gingiva) is of utmost importance. Placement of the submarginal incision within or close to the free gingiva must be avoided under all circumstances, as this would cut off the blood supply to the GM and lead to subsequent gingival recession (Velvart *et al.* 2005). Patients must also be informed about the possible risk of scar formation with the submarginal incision technique when deciding on the most appropriate flap design. Alternatively, the PBI should be considered in the aesthetic zone to avoid papilla shrinkage.

The presence, type and quality of restorations – with special reference to the position of the restoration margin in relation to the gingiva – have also been recommended to be determined in patients subjected to

Table 7 Distribution of teeth per incision technique ($n = 184$)

	Intrasulcular incision		Papilla base incision		Submarginal incision	
Teeth	*n*	%	*n*	%	*n*	%
Maxillary anterior	21	17.8	3	9.1	26	78.8
Maxillary premolars	25	21.2	9	27.3	4	12.1
Maxillary molars	15	12.7	8	24.2	1	3.0
Mandibular anterior	1	0.8	1	3.0	2	6.0
Mandibular premolars	12	10.2	1	3.0	0	0
Mandibular molars	44	37.3	11	33.3	0	0
Total	118	100	33	100	33	100

Table 8 Distribution of teeth per restoration ($n = 184$)

	No restoration		Filling		Crown	
Teeth	*n*	%	*n*	%	*n*	%
Maxillary anterior	3	21.4	13	36.1	34	25.4
Maxillary premolars	3	21.4	5	13.9	30	22.4
Maxillary molars	6	42.9	8	22.2	10	7.5
Mandibular anterior	0	0	2	5.6	2	1.5
Mandibular premolars	0	0	2	5.6	11	8.2
Mandibular molars	2	14.3	6	16.7	47	35.1
Total	14	100	36	100	134	100

Table 9 Distribution of restoration per incision ($n = 184$)

	Intrasulcular incision		Papilla base incision		Submarginal incision	
Teeth	*n*	%	*n*	%	*n*	%
No restoration	11	9.3	1	3.0	2	6.1
Filling	21	17.8	7	21.2	8	24.2
Crown	86	72.9	25	75.8	23	69.7
Total	118	100	33	100	33	100

apical surgery (Velvart *et al.* 2005). In this study, cases with nonrestorable teeth or poor restoration margins were not subjected to apical surgery. Manipulations of soft tissues in areas with restoration margins placed subgingivally can lead to exposure of these margins because of recession following apical surgery. It is important to inform the patient about this possible sequela, in particular for buccal sites in the aesthetic zone. However, no clinical study appears to have evaluated the influence of restoration margins on soft tissue healing following apical surgery. In this study, the presence of a crown margin led to a greater change of GM (=more gingival recession) in buccal sites compared with the presence of a filling margin or the absence of a restoration margin. However, the differences were not statistically significant. Only a single parameter, i.e. PD at the mid-buccal site, proved to be significant when the presence of a crown margin and a filling margin were compared. This study did not attempt to correlate the initial level of a restoration margin present (=initial GM value) with the subsequent changes of the evaluated periodontal parameters following apical surgery. However, the pre-operative mean GM level at mid-buccal sites was flush (−0.02 mm) with the crown margin in teeth with crown restorations compared with recessions present for teeth with filling restorations (−0.65 mm) or to teeth without restorations (−0.57 mm). At the 1-year follow-up, teeth with crown restorations demonstrated a mean GM of −0.38 mm at the mid-buccal site, meaning that now an exposure of the crown margin had occurred. This finding underlines the importance of patient information about possible changes of soft tissue levels following apical surgery. The distribution of restoration margin per type of incision, as listed in Table 9, was homogenous.

The study by Jansson *et al.* (1997) also included the parameter 'restoration' when recruiting cases, i.e. if a restoration was found on the buccal surface of the test tooth, restorations were also required on the buccal surfaces of the control teeth. However, no data were reported with respect to healing outcome in teeth with restorations compared to teeth without restorations.

In this study, smokers and nonsmokers did not exhibit any significant differences for the evaluated parameters. A recent review reported that there are no papers in the literature that discuss the variables of smoking and surgical endodontics (Duncan & Pitt Ford 2006). Meanwhile, a clinical study evaluating various clinical and radiographic predictors for healing outcome after periapical surgery found no significant difference between smokers and nonsmokers (von Arx *et al.* 2007). This is in contrast to equivalent surgical periodontal studies (Scabbia *et al.* 2001, Trombelli *et al.* 2003, Martins *et al.* 2004). In fact, there are differences in healing following periodontal and apical surgery: periodontal surgery involves epithelial healing in an inflamed area and healing by secondary intention, whilst this is generally not the case with apical surgery. In addition, apical surgery is unlikely to involve repositioning of the flap after removal of diseased gingival tissues (Duncan & Pitt Ford 2006).

In this study, mean plaque and bleeding indices were very low and did not change significantly over time, and no significant differences were found when plaque

and bleeding indices of smokers and nonsmokers were compared. Little to no influence was found when comparing changes of periodontal parameters across the different tooth groups.

Conclusions

Within the limits of this prospective, nonrandomized, and clinical study, the following conclusions can be drawn:

1. In general, buccal compared with lingual sites demonstrated greater changes in PD, level of GM, and level of clinical attachment 1 year after apical surgery.

2. The intrasulcular incision demonstrated greater changes in the levels of the GM and the clinical attachment than the other incision techniques, meaning more recession of the GM and greater loss of attachment.

3. The presence and type of restoration, the tooth group or the smoking habit of the patient were not found to influence the observed changes significantly in periodontal parameters.

4. The clinical relevance of this study is that the incision technique, in particular the intrasulcular incision, may lead to changes in periodontal parameters following apical surgery.

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