Five-year Changes in Periodontal Parameters after Apical Surgery

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Abstract

Introduction: Most clinical studies on the outcome of apical surgery concentrate on periapical healing based on radiographic and clinical characteristics (signs and symptoms). This study focuses on long-term changes in periodontal parameters after apical surgery. **Methods:** Periodontal parameters (ie, probing depth [PD], level of gingival margin [GM], and calculated clinical attachment level [CAL]) were collected at baseline and at 1 and 5 years after apical surgery. Changes in PD, GM, and CAL were calculated over time and were also evaluated in relation to patient-, tooth-, and treatment-related covariables. **Results:** One hundred eighty-six of 242 initially identified teeth could be evaluated. Significant changes in GM and CAL were observed at facial sites during the first year after surgery (mean recession of GM was 0.29 mm, mean CAL loss was 0.20 mm), but none of the periodontal parameters significantly changed between 1 and 5 years after apical surgery. With regard to covariables, the type of incision technique was found to be the major factor affecting changes in GM and CAL between baseline and 1 year after surgery. Age, smoking, and type of periapical healing were the variables influencing the periodontal parameters over the longer observation period of up to 5 years. **Conclusions:** Patients should be informed about possible changes in periodontal parameters (gingival recession and loss of attachment) after apical surgery. The surgery itself appears to account for changes observed during the first year, whereas patient- and healing-related factors seem to affect periodontal changes seen thereafter. *(J Endod 2011;37:910–918)*

Key Words

Apical surgery, clinical attachment level, follow-up study, gingival margin, probing depth

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Apical surgery is a method of surgical tooth maintenance and is often considered a last resort before tooth extraction. A tooth presenting with a nonhealing or recurrent apical lesion is normally subjected to nonsurgical root canal retreatment. However, in certain situations, nonsurgical root canal retreatment is not possible or is associated with risks, and apical surgery may be offered as a treatment alternative. The main objective of apical surgery after 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 periapical tissues. This seal is usually accomplished by root-end cavity preparation, with subsequent root-end filling. The success of apical surgery is usually determined with follow-up radiographs and clinical examinations; these show that the previous periapical radiolucency has disappeared, the tooth is without clinical signs, and the patient is free of pain. The vast majority of clinical studies on apical surgery report the radiographic outcome with regard to periapical healing. Only a few studies have described gingival and mucosal healing, including periodontal parameters after apical surgery (1–3).

In apical surgery, a mucoperiosteal flap is raised to gain access and to treat the lesion and manage the affected root end. Flap elevation and the exposure of marginal tissues (ie, periodontal tissue and alveolar bone) may result in changes in tissue levels around the teeth within the flap area after apical surgery. Experimental studies in dogs (4, 5) and in cats (6) have documented some of the clinical and histological changes after mucogingival flap surgery used in surgical endodontics. However, these data cannot be transferred directly to the clinical situation in patients in whom multiple patient-, tooth-, and treatment-related covariables may influence the mucogingival healing.

Current clinical reports on soft-tissue changes after apical surgery have a limited 1-year observation period. In 59 patients, Jansson et al (1) documented a significantly greater ($P = .04$) mean loss of clinical attachment level (CAL) of 0.85 mm for root-end resected teeth with unsuccessful healing compared with only 0.15 mm in successfully healed teeth. Velvart et al (7) compared the effect of two different incision techniques on interdental papilla height in 12 patients. The intrasulcular incision produced significantly ($P < .001$) more papilla shrinkage (0.98 mm) compared with the papilla-base incision (−0.06 mm). In a third study, the effect of three different incision techniques on gingival margin (GM) and CAL was assessed in 184 teeth with apical surgery (2). The study reported that the type of incision significantly influenced the changes in GM and CAL levels over the observation period of 1 year.

The objectives of the present observational study were twofold: (1) to document changes in periodontal parameters in teeth with apical surgery over a long-term period of 5 years and (2) to correlate the documented changes with patient-, tooth-, and treatment-related covariables.

Materials and Methods

Patient Selection

The cases for the present study were recruited from patients who underwent apical surgery from 2000 to 2004. A total of 242 patients with 267 treated teeth were consecutively enrolled for this analysis. Patients were fully instructed about the surgical procedure, postoperative care, follow-up examinations, and alternative treatment options. Each patient signed a consent form according to the declaration of Helsinki. Because the present study was not a clinical trial but rather an observational study (no new technique, medical/surgical material, or medication was tested), approval by the university's ethical committee was not necessary.

Surgical Technique

Apical surgery was performed with 3 to 4 mL of local anesthesia (articaine 4% with 1:100,000 epinephrine; Ultracain D-S forte, Sanofis-Aventis, Meyrin, Switzerland). The preparation of the full-thickness mucoperiosteal flap was done with a small surgical spoon, tissue elevators, and gauze attached to a hemostat. Flap reflection was accomplished with retraction sutures, and the surgical site and the reflected mucoperiosteal flap were regularly rinsed with saline to prevent dehydration. Osteotomy was performed with a straight hand-piece using round burs and copious saline irrigation. Affected roots were then resected approximately 3 mm from the apex. After debridement of the pathological tissue, hemostasis of the bony crypt was achieved with a paste containing aluminum chloride (Expasyl; Produits Dentaires Pierre Rolland, Merignac, France) and/or a solution of ferric sulphate (Stasis; Belport Co, Camarillo, CA). Caution was exercised to avoid contamination of the marginal periodontium with the hemostatic agent. After staining of the surgical area with methylene blue (1% Methylthionin HCL; Dr. G. Bichsel AG, Interlaken, Switzerland), the root end was inspected and root-end cavities were prepared with sonic-driven microtips (KaVoSONIC Retro; KaVo Dental GmbH, Biberach, Germany). The root-end cavities were either filled with SuperEBA (Staident International, Staines, UK) or with mineral trioxide aggregate (Dentsply Tulsa Dental, Tulsa, OK). Alternatively, a shallow concavity was prepared in the cut root face using round diamond burs, with subsequent placement of dentin-bonded resin composite (Retroplast; Retroplast Trading, Rorvig, Denmark). The selection of the root-end filling material was not randomized. After cleaning of the wound area, primary wound closure was accomplished with multiple interrupted sutures placed 2 to 3 mm apart. The suture material included a nonresorbable polyamide monofilament of sizes 5-0, 6-0, and 7-0 (Seralon; Serag Wiessner KG, Naila, Germany). All cases were treated by the same surgeon (TvA).

Medication and Follow-up

All patients were given nonsteroidal analgesics and were instructed to rinse their mouth twice daily with 0.1% chlorhexidine-digluconate for 10 days. Antimicrobial medication was not prescribed routinely. When antibiotics were given, they included 2 g amoxicillin-clavulanic acid, or alternatively 600 mg clindamycin to be taken 2 hours preoperatively. Antimicrobial medication was mainly administered for medical reasons or when treating cases with a (sub)acute periapical infection. Patients were seen 4 to 7 days after surgery for suture removal. All patients were recalled 1 and 5 years after apical surgery for the follow-up examinations.

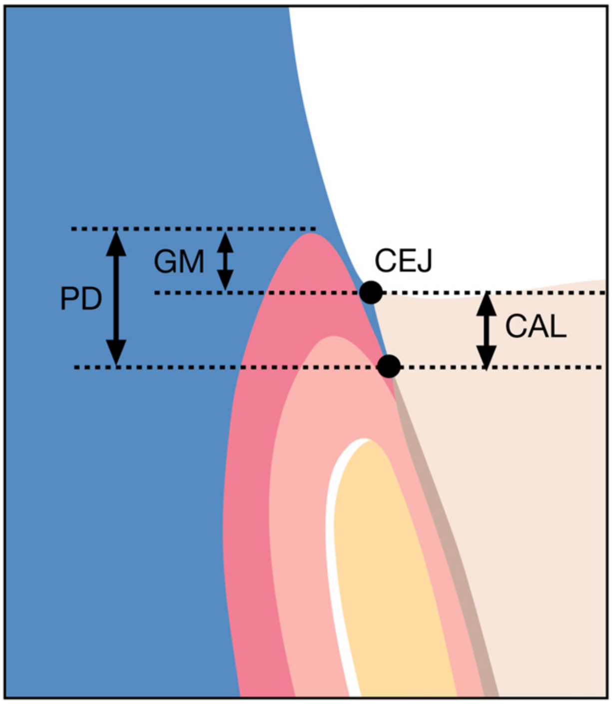

Figure 1. A schematic illustration of the periodontal measurements.

Exclusion Criteria

In 22 patients, more than one tooth was treated. For statistical reasons, only one tooth per patient was randomly selected for further analysis, resulting in a total of 242 treated teeth in 242

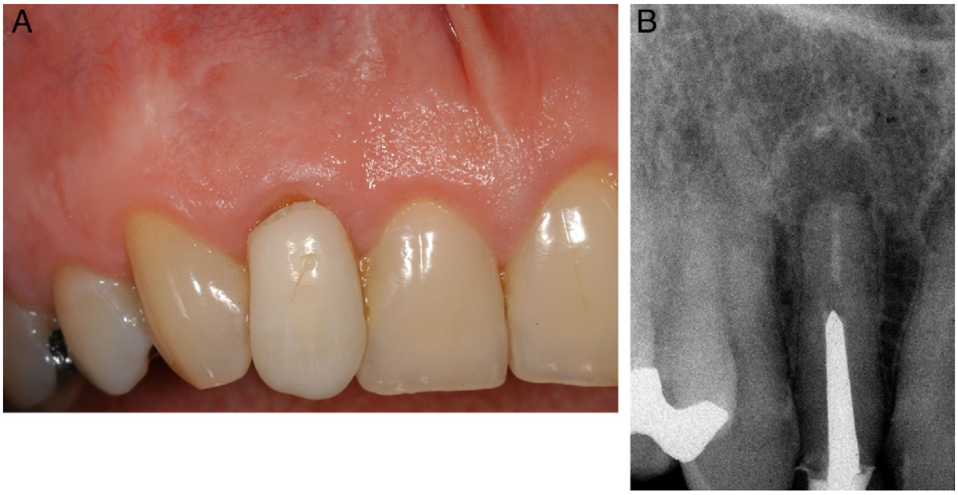

Figure 2. (*A*) The clinical situation of the right maxillary lateral incisor subjected to apical surgery in a 55-year-old male patient. (*B*) The periapical radiograph shows a distinct apical lesion.

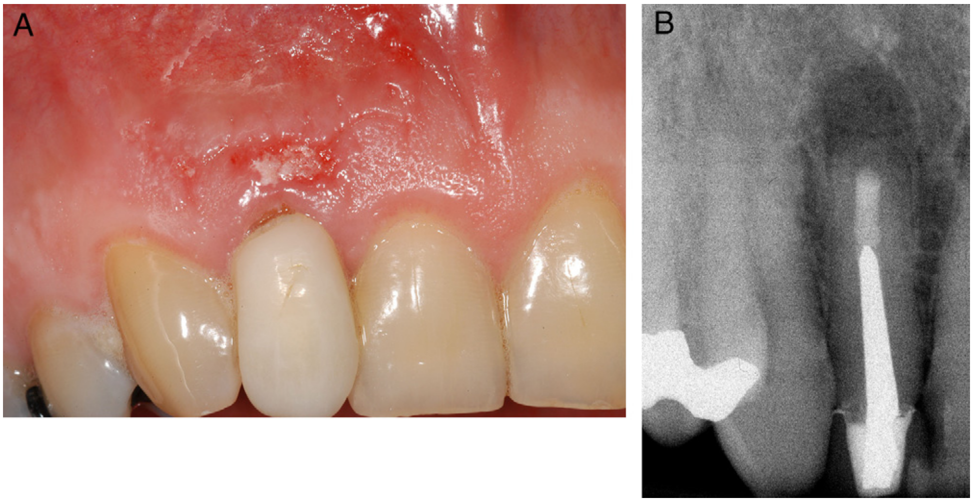

Figure 3. (*A*) The clinical situation after suture removal 4 days after apical surgery. (*B*) The postsurgical radiograph shows the root-end filling.

patients (randomization according to www.graphpad.com/quickcalcs/randomize1/cfm).

Collection of Data

Primary study parameters included the probing depth (PD), the level of the GM, and the CAL. PD and GM were taken with a periodontal probe (Colorvue Tip; Hu-Friedy, Leimen, Germany) to the nearest 0.5 mm preoperatively (baseline) and 1 and 5 years after apical surgery. The data were collected at four sites of the treated tooth: mesiobuccal, midbuccal, distobuccal, and midlingual. Measurements at the mesiobuccal and distobuccal sites were taken at the buccal line angles of the tooth. The reference for the gingival margin was the cementoenamel junction (CEJ), or the margin of a restoration, if present. When the CEJ or margin of a restoration was below the GM (thus not visible), the GM was given a negative value; when the CEJ or margin of a restoration was above the GM (thus visible), the GM was given a positive value. The clinical attachment level was calculated as follows: CAL = PD + GM (Fig. 1).

Secondary study variables (with subcategories) included the following: (1) age (<45 years, ≥45 years), (2) sex (male, female), (3) smoking habit (smoker, nonsmoker), (4) type of treated tooth (maxillary anterior teeth including incisors and canines, maxillary premolars, maxillary molars, mandibular anterior teeth including incisors and canines, mandibular premolars, and mandibular molars), (5) type of restoration adjacent to gingival margin (crown, filling, and none), (6) type of incision technique (intrasulcular incision, papilla-base incision, and submarginal incision), and (7) result of periapical healing 5 years after surgery (healed, not healed). The healing after 5 years was judged clinically and radiographically. The radiographs were taken with a paralleling technique and were evaluated independently by three examiners. Follow-up radiographs were compared with postoperative radiographs (Figs. 2–9) to define radiographic periapical healing as either complete, incomplete (scar tissue formation), uncertain (some reduction of former radiolucency), or unsatisfactory (no reduction or enlargement of former radiolucency) according to the criteria established by Rud et al (8) and Molven et al (9). A specific healing class was assigned when two examiners agreed on the same healing class. The clinical examination assessed whether signs or symptoms of periapical pathosis were present (10).

For statistical reasons, the results were dichotomized into healed or not healed cases (11): healed cases: the radiograph showed complete healing of the previous radiolucency or incomplete healing

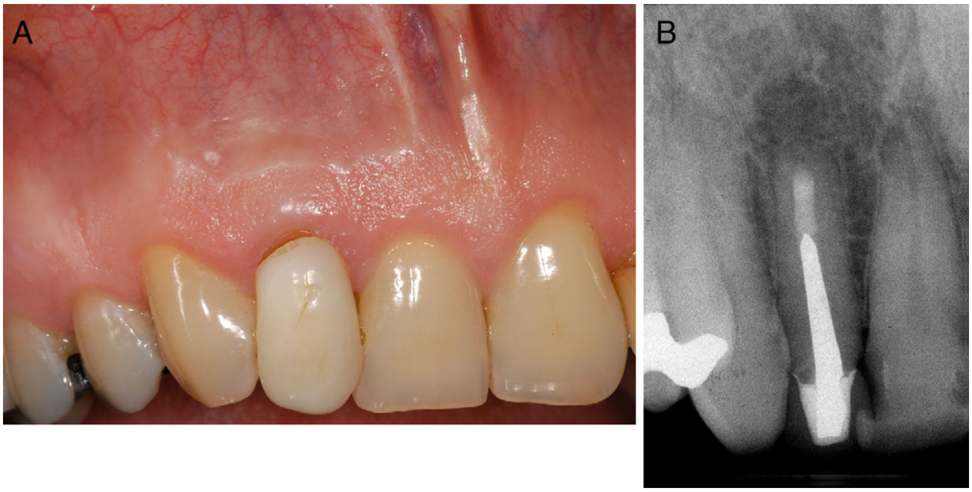

Figure 4. (*A*) The 1-year clinical picture shows normal and healthy tissues. (*B*) The radiograph taken 1 year after apical surgery shows the formation of a new periodontal ligament space at the cut root face.

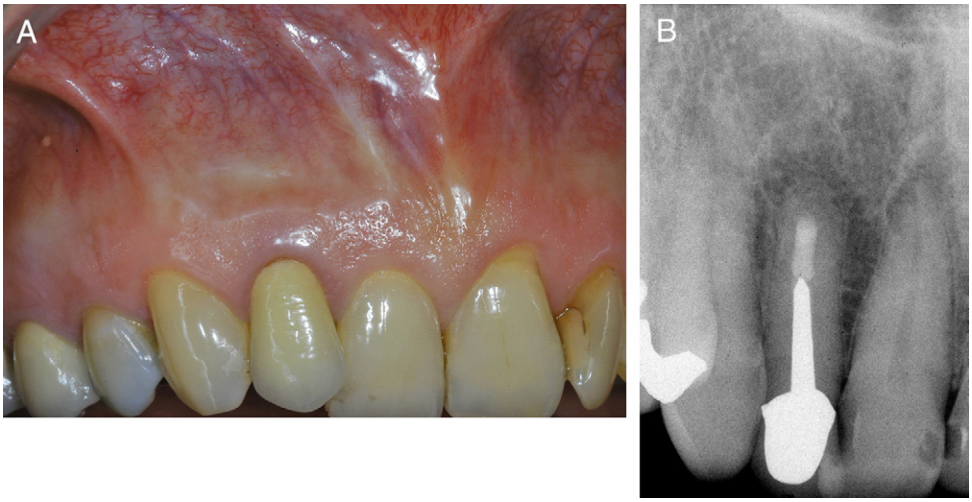

Figure 5. (*A*) The 5-year clinical examination shows normal and healthy tissues. (*B*) The 5-year radiograph exhibits complete healing of the previous periapical radiolucency.

and no clinical signs or symptoms were present and (2) not healed cases: the radiographic healing was assessed as uncertain or unsatisfactory, or clinical signs or symptoms were present irrespective of the radiographic healing. The tooth was used as the unit of assessment. If, for example, a multirooted tooth presented with two healed roots and one not healed root, the case was classified as not healed.

Analysis of Data

All recorded measurements were collected in Excel (Microsoft, Redmond, WA) spreadsheets for further analysis. Because of the amount of data, the data on mesiobuccal, midbuccal, and distobuccal sites were subsequently pooled as data of facial sites. Mean values of PD, GM, and CAL were calculated for facial and lingual sites for baseline, 1-year, and 5-year examinations of all patients but also for subcategories of secondary study variables (ie, sex: male and female patients). The assessment of the actual changes in the periodontal parameters was calculated as follows:

$\Delta \triangle$ 0–1 = $\sum$ 1-year - $\sum$ preoperative (calculated changes for period from baseline to 1-year examination)
$\triangle$ 1–5 = $\sum$ 5-year - $\sum$ 1 year (calculated changes for period from 1-year to 5-year examinations)
$\triangle$ 0–5 = $\sum$ 5-year - $\sum$ baseline (calculated changes for period from baseline to 5-year examination)

How positive and negative values are assigned for the calculated changes in PD, GM, and CAL is explained in Table 1.

Statistics

Pairwise comparisons of measurements per patient were tested with Wilcoxon signed rank test for paired samples. Comparisons of measurement differences across subcategories per variable (sex: male vs female) were tested with Kruskal-Wallis' nonparametric analyses of variance. All *P* values were calculated using the statistical software R, version 2.10.1 (The R Foundation for Statistical Computing, Vienna, Austria). Because of the exploratory nature of the statistical analysis, no correction for multiple testing was applied. Therefore, results significant at the 5% level have to be judged cautiously.

The *P* values were connected to the following null hypotheses: (1) there is no change in PD/GM/CAL between baseline and 1 year for facial/lingual sites (six hypotheses); (2) there is no change in PD/GM/CAL between 1 and 5 years for facial/lingual sites (six hypotheses); (3) there is no change in PD/GM/CAL between baseline and 5 years for facial/lingual sites (six hypotheses); (4) there is no difference in PD/GM/CAL comparing facial and lingual sites at baseline, at 1 year, and at 5 years (nine hypotheses); (5) the changes in PD/GM/CAL between baseline and 1 year for facial/lingual sites are equivalent when subcategories are compared (sex: male vs female) (six hypotheses per variable); (6) the changes in PD/GM/CAL between 1 and 5 years for facial/lingual sites

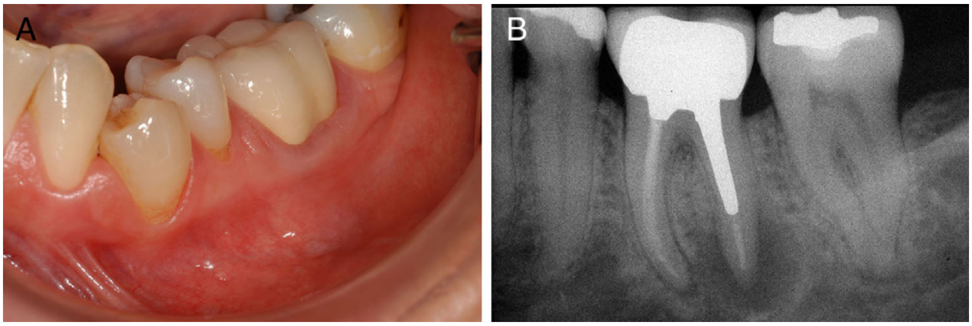

Figure 6. (*A*) The clinical situation of the left first mandibular molar subjected to apical surgery in a 49-year-old female patient. (*B*) The periapical radiograph shows a small lesion at the mesial root and a large lesion at the distal root of the left first mandibular molar.

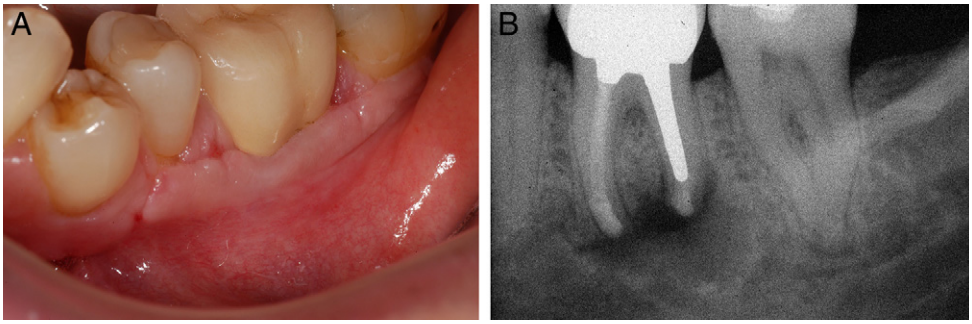

Figure 7. (*A*) The clinical situation after suture removal 4 days after apical surgery. (*B*) The postsurgical radiograph shows that both roots have been resected and root-end fillings have been placed.

are equivalent when subcategories are compared (sex: male vs female) (six hypotheses per variable); and (7) the changes in PD/GM/CAL between baseline and 5 years for facial/lingual sites are equivalent when subcategories are compared (sex: male vs female) (six hypotheses per variable).

Results

Of 242 initially identified teeth, a total of 186 (in the same number of patients) could be evaluated. The dropout rate was 56 of 242 teeth (23%) (Table 2). The patient sample consisted of 102 female patients (54.8%) and 84 male patients (45.2%). The mean age of the patients was 49.7 years (range, 9–81 years).

The mean values of baseline, 1-year, and 5-year measurements of PD, GM, and CAL for all patients are shown in Table 3. For facial sites, the mean PD was significantly lower after 1 year ($P < .01$) and after 5 years ($P < .001$) compared with baseline but remained stable from 1 year to 5 years after surgery. No significant changes were observed for PD at lingual sites. With regard to the mean GM, values significantly changed both for facial and lingual sites when baseline values were compared with values at 1 year ($P < .001$) and 5 years ($P < .001$). No significant changes in GM were noted between 1 and 5 years after surgery. The mean CAL significantly increased at facial sites from baseline (2.47 mm) to 1 year (2.67 mm) and to 5 years (2.74 mm) ($P < .0001$). However, the change in facial CAL from 1 to 5 years was not significant ($P = .33$). At lingual sites, the only significant change in CAL was observed from baseline (2.48 mm) to 5 years (2.69 mm) ($P < .05$). The comparison of lingual to facial values of PD/GM/CAL revealed no significant differences at any study times.

The changes in the periodontal parameters over time per variable are presented separately for PD, GM, and CAL (Tables 4–6). With regard to the mean changes in PD, the following variables showed significant differences when their subcategories were compared (Table 4): (1) PD facial sites Δ0–5: sex, age, smoking habit, and type of restoration; (2) PD facial sites Δ1–5: type of treated tooth; (3) PD lingual sites Δ0–5: smoking habit; and (4) PD lingual sites Δ1–5: smoking habit.

Regarding the mean changes in GM, the following variables showed significant differences when their subcategories were compared (Table 5): (1) GM facial sites Δ0–1: sex, type of incision technique; (2) GM facial sites Δ0–5: age; (3) GM facial sites Δ1–5: age; and (4) GM lingual sites Δ0–1: type of incision technique.

With regard to the mean changes in CAL, the following variables showed significant differences when their subcategories were compared (Table 6): (1) CAL facial sites Δ0–1: type of incision technique; (2) CAL facial sites Δ0–5: healing classification; (3) CAL facial sites Δ1–5: age, type of treated tooth, healing classification; (4) CAL lingual sites Δ0–1: type of incision technique; (5) CAL lingual sites Δ0–5: smoking habit, healing classification; and (6) CAL lingual sites Δ1–5: smoking habit.

Discussion

The present clinical study reports the changes in periodontal parameters (PD, GM, and CAL) of 186 teeth treated with apical surgery over an observation period of 5 years. Changes in PD, GM, and CAL were calculated from baseline to 1 year, from 1 year to 5 years, and from baseline to 5 years. In addition, covariables such as patient variables (sex, age, smoking habit), tooth variables (type of treated tooth, type of tooth restoration), and treatment variables (type of incision technique, type of healing) were assessed to determine a possible influence on changes in periodontal parameters.

To our knowledge, this is the first study to document long-term changes in periodontal parameters following apical surgery. The

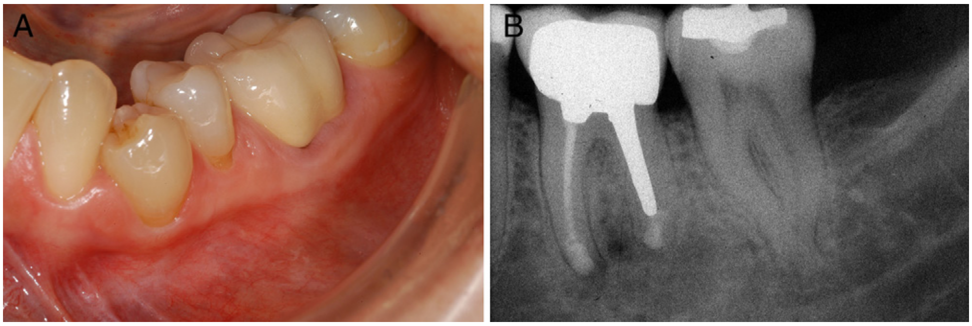

Figure 8. (*A*) The 1-year clinical picture shows normal and healthy tissues. (*B*) The radiograph taken 1 year after apical surgery shows nearly complete resolution of the former radiolucency.

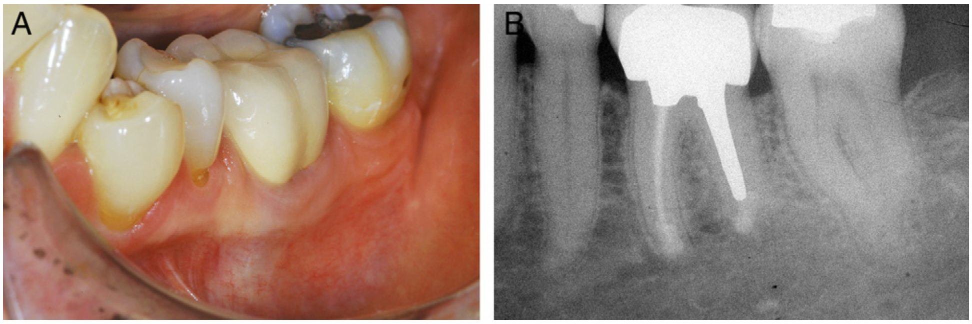

Figure 9. (*A*) The 5-year clinical examination shows normal and healthy tissues. (*B*) The 5-year radiograph exhibits complete healing around both resected roots.

strengths of the study further include the number of treated teeth; the fact that one surgeon treated all cases; the inclusion of covariables; and the correlation of the changes in PD, GM, and CAL with the outcome after 5 years, with radiographs assessed by three examiners independently. On the other hand, caution must be exercised when interpreting the results because other important information (and possible confounding factors) was not collected: general periodontal status of patient, gingival biotype of the treated tooth, periodontal maintenance, and changes in medical conditions over the study period.

The overall mean values of PD, GM, and CAL at three different study points showed the following changes over the observation period of 5 years; PD at facial sites was significantly reduced from baseline to 1 year but remained stable from 1 to 5 years. No changes in PD were noted at lingual sites. GM was located coronal to the CEJ (or to a gingival restoration margin) at baseline at facial and lingual sites. At the 1-year examination, GM was located apical to the CEJ (facially and lingually), meaning that the cervical root portion or a restoration margin became visible (ie, gingival recession had occurred). The calculated mean change in GM level from baseline to 1 year was statistically significant. The gingival recession continued from 1 year to 5 years at both facial and lingual sites, but the changes were not statistically significant. The loss of CAL was significant at facial sites from baseline to 1 year and from baseline to 5 years but not from 1 to 5 years. At lingual sites, the loss of CAL was significant from baseline to 5 years.

Many cofactors may affect the changes in periodontal parameters of teeth treated with apical surgery. On a patient level, sex, age, smoking habit, medical condition, general periodontal status, oral hygiene, and periodontal maintenance may account for such changes. On a tooth level, type of tooth, type and quality of restoration (margin), and periodontal and alveolar bone condition may influence periodontal healing after apical surgery. Finally, the healing of marginal tissues may be associated with treatment factors, such as length of surgery, type of incision technique and flap design, technique of wound closure, and medication. The number of possible covariables is complex and, thus, is particularly difficult to define the variables that play a significant role with regard to periodontal healing after apical surgery.

TABLE 1. The Definition of Calculation of Changes in Periodontal Parameters

	Positive value of mean change	Negative value of mean change
PD	Increase in probing depth	Reduction of probing depth
GM	Apical displacement of gingival margin	Coronal displacement of gingival margin
CAL	Loss of clinical attachment	Gain in clinical attachment

Previous clinical studies have shown that various factors may influence changes in periodontal parameters after apical surgery; however, this information is limited to a follow-up period of 1 year. Jansson et al (1) studied a possible relationship between apical and marginal healing in apical surgery. Periodontal parameters (facial sites only) were assessed in 59 patients at the time of surgery and 1 year thereafter. The change in clinical attachment level from baseline (2.97 mm) to re-examination (3.24 mm) was significant ($P < .05$). With regard to healing after 1 year, teeth with unsuccessful healing showed significantly ($P = .04$) more loss of CAL (0.85 mm) compared with successfully healed cases (0.15 mm). The present study also found a significant loss of CAL from baseline (2.47 mm) to 1 year (2.67 mm) at facial sites, with further attachment loss noted at 5 years (2.74 mm). However, a similar loss of CAL was also observed for lingual sites (with no significant differences between facial and lingual sites), indicating that the loss of CAL may not only be associated with the surgery itself.

The possible relationship between apical and marginal healing after apical surgery, as reported by Jansson et al (1), was corroborated in the present study. Significantly more loss of CAL was found from baseline to 5 years at facial (0.58 mm) and lingual sites (0.66 mm) in not-healed cases compared with healed cases (0.21 mm and 0.12 mm, respectively). It appears that a persistent endodontic infection may be a potential contributing risk factor for progressing marginal attachment loss. It was suggested that the infected root canal acted as a reservoir of bacteria via dentinal tubules and accessory canals, maintaining periradicular as well as marginal inflammation (12, 13). Under clinical conditions, root cementum is frequently removed upon scaling and root planing, and this may be the most important factor for the reported findings in the studies of Jansson et al (12, 13). However, in individuals who are not susceptible to periodontal disease, root cementum normally remains intact and may thus prevent bacteria in infected root canals from exerting pathological influences on the periodontal tissues.

TABLE 2. Summary of Drop-out Cases (n = 56)

Patient did not want to attend the 5-year follow-up	23
Patient could not be contacted	3
Patient had died	1
Tooth extracted because of vertical root fracture	10
Tooth extracted because of deep crown fracture	3
Tooth extracted because of invasive cervical resorption	1
Tooth extracted for strategic reason (change of treatment plan)	1
Tooth was re-operated during study period	6
Data set not complete	8
Total drop-outs	56

TABLE 3. Mean Values of PD, GM, and CAL at Baseline and at 1 and 5 Years after Apical Surgery (n = 186)

	Baseline	1-year examination	5-year examination
Probing depth (PD)			
Facial	2.61 mm[a,b]	2.51 mm[a]	2.50 mm[b]
Lingual	2.59 mm	2.53 mm	2.56 mm
Gingival margin (GM)			
Facial	−0.13mm[c,d]	0.16 mm[c]	0.24 mm[d]
Lingual	−0.10mm[e,f]	0.08 mm[e]	0.13 mm[f]
Clinical attachment level (CAL)			
Facial	2.47 mm[g,h]	2.67 mm[g]	2.74 mm[h]
Lingual	2.48 mm[i]	2.60 mm	2.69 mm[i]

Gingival margin: a negative value means that gingival margin is coronal to cemento-enamel junction; a positive value means that gingival margin is apical to cemento-enamel junction. Identical superscripts denote a statistically significant difference: $P < .05^{i}$; $P < .01^{a}$; $P < .001^{b,c,d,e,f,g,h}$.

Miyashita et al (14), in a total of 155 pairs of contralateral teeth (test tooth was either endodontically treated or had a periapical radiolucency; control tooth had normal periapical conditions and no evidence of root canal treatment), examined the extent to which the marginal alveolar bone may be influenced by the condition of the dental pulp. With clinical parameters similar between teeth in the two groups in terms of visible plaque, bleeding on probing, probing depth, and attachment level, the results failed to show a correlation between reduced marginal bone support and endodontic status.

In a previous clinical study with a 1-year follow-up, von Arx et al (2) evaluated factors possibly contributing to changes in periodontal parameters after apical surgery. In 184 teeth, significant differences between the intrasulcular and submarginal incisions were found for changes in GM and CAL. For example, with the intrasulcular incision, there was mean recession of 0.42 mm at facial sites, whereas using the submarginal incision, there was a gain of 0.05 mm. In a study about gingival recession after apical surgery in the esthetic zone, von Arx et al (3) reported significantly less gingival recession with the submarginal incision compared with the intrasulcular incision, papilla-base incision, or papilla-saving incision. In the present study, the type of incision technique was also found to significantly affect changes in GM and CAL from baseline to 1 year, both at facial and lingual sites. However, changes in GM and CAL from 1 to 5 years and from baseline to 5 years did not differ across the three incision techniques, indicating that the incision technique mainly affected the marginal healing within the first year after apical surgery but not thereafter. In the present study, the selection of the decision technique was not randomized but was rather based on the site of treatment (anterior vs posterior teeth), the periodontal condition, and the size and location of the periapical lesion.

With regard to age, the present study found significantly more gingival recession in older than in younger patients (facial sites: 1 to 5 years and baseline to 5 years) and similarly significantly more loss of CAL in older than in younger patients (facial sites: 1 to 5 years). Because age had no influence on the study period baseline to 1 year, the noted changes appear to be related to the aging phenomenon rather than to the surgery itself. In fact, the periodontal literature shows that age is strongly associated with gingival recession

TABLE 4. Mean Changes in Probing Depth (n = 186) from Baseline to 1 Year (Δ 0–1), from 1 to 5 Years (Δ 1–5), and from Baseline to 5 Years (Δ 0–5)

Variables	Subcategories	n	Δ 0–1 facial	Δ 0–1 lingual	Δ 1–5 facial	Δ 1–5 lingual	Δ 0–5 facial	Δ 0–5 lingual
All patients	—	186	−0.10	−0.06	0.00	0.03	−0.11	−0.03
Gender	Female	102	−0.06	−0.03	0.03	−0.02	−0.03[a]	−0.06
	Male	84	−0.16	−0.10	−0.04	0.10	−0.20[a]	0.00
Age	< 45 years	65	−0.03	−0.02	0.02	0.03	−0.01[b]	0.02
	≥ 45 years	121	−0.14	−0.09	−0.02	0.03	−0.16[b]	−0.06
Smoking	No	135	−0.13	−0.08	−0.03	−0.07[c]	−0.16[d]	−0.15[e]
	Yes	51	−0.04	−0.01	0.06	0.29[c]	0.02[d]	0.28[e]
Tooth	Maxillary anterior teeth*	58	−0.15	−0.05	−0.02[f]	−0.02	−0.18	−0.07
	Maxillary premolars	34	−0.20	−0.18	−0.04[f]	0.01	−0.24	−0.16
	Maxillary molars	27	−0.10	0.13	−0.01[f]	−0.26	−0.10	−0.13
	Mandibular anterior teeth*	6	−0.25	−0.33	0.17[f]	0.42	−0.08	0.08
	Mandibular premolars	11	−0.20	−0.32	−0.02[f]	0.09	−0.21	−0.23
	Mandibular molars	50	0.05	−0.01	0.03[f]	0.19	0.08	0.18
Restoration	Crown	133	−0.14	−0.07	−0.05	0.02	−0.19[g]	−0.05
	Filling	32	−0.01	−0.05	0.19	0.05	0.18[g]	0.00
	None	21	−0.05	−0.02	−0.01	0.05	−0.06[g]	0.02
Incision	Intrasulcular	112	−0.07	−0.07	−0.05	0.05	−0.12	−0.02
	Papilla-base	36	−0.19	−0.01	0.06	0.04	−0.13	0.03
	Submarginal	38	−0.13	−0.09	0.06	−0.04	−0.07	−0.13
Healing	Healed	158	−0.13	−0.08	−0.03	0.02	−0.16	−0.07
	Not healed	28	0.02	0.05	0.15	0.11	0.17	0.16

Positive values = increased probing depth.

Negative values = reduced probing depth.

Identical superscripts denote statistically significant differences across subcategories per variable: $P < .05^{a,b,c,d,g}$; $P < .01^{e,f}$.

*Anterior teeth = incisors and canines.

TABLE 5. Mean Changes in Gingival Margin (n = 186) from Baseline to 1 Year (Δ 0–1), from 1 to 5 Years (Δ 1–5), and from Baseline to 5 Years (Δ 0–5)

Variables	Subcategories	n	Δ 0–1 facial	Δ 0–1 lingual	Δ 1–5 facial	Δ 1–5 lingual	Δ 0–5 facial	Δ 0–5 lingual
All patients	—	186	0.29	0.18	0.08	0.05	0.37	0.23
Gender	Female	102	0.19[a]	0.18	0.07	0.01	0.27	0.19
	Male	84	0.41[a]	0.18	0.08	0.10	0.49	0.29
Age	< 45 years	65	0.30	0.14	−0.11[b]	0.06	0.19[c]	0.20
	≥ 45 years	121	0.29	0.21	0.17[b]	0.05	0.46[c]	0.25
Smoking	No	135	0.31	0.24	0.07	0.02	0.38	0.26
	Yes	51	0.24	0.04	0.09	0.14	0.33	0.18
Tooth	Maxillary anterior teeth*	58	0.41	0.17	−0.05	0.00	0.36	0.17
	Maxillary premolars	34	0.20	0.04	0.10	−0.01	0.30	0.03
	Maxillary molars	27	0.02	0.09	0.07	0.06	0.10	0.15
	Mandibular anterior teeth*	6	0.72	1.00	0.19	−0.33	0.92	0.67
	Mandibular premolars	11	0.23	0.59	0.23	−0.14	0.45	0.45
	Mandibular molars	50	0.33	0.15	0.16	0.24	0.48	0.39
Restoration	Crown	133	0.32	0.16	0.10	0.08	0.42	0.24
	Filling	32	0.16	0.39	0.10	0.03	0.26	0.42
	None	21	0.30	0.02	−0.11	−0.10	0.19	−0.07
Incision	Intrasulcular	112	0.38[d]	0.31[e]	0.09	0.03	0.47	0.34
	Papilla-base	36	0.33[d]	0.00[e]	−0.02	0.00	0.31	0.00
	Submarginal	38	−0.02[d]	−0.01[e]	0.14	0.16	0.12	0.14
Healing	Healed	158	0.30	0.15	0.06	0.04	0.36	0.19
	Not healed	28	0.26	0.38	0.15	0.13	0.41	0.50

Positive values = recession of gingival margin.

Negative values = inflation of gingival margin.

Identical superscripts denote statistically significant differences across subcategories per variable: $P < .05^{c}$; $P < .01^{a,b,d,e}$.

*Anterior teeth = incisors and canines.

(15) and attachment loss (16). A cross-sectional study reported a nonlinear correlation of prevalence, extent, and severity of gingival recession with increasing age (15). The risk of attachment loss was also reported to correlate with age, with odds ratios ranging from 1.72 (95% confidence interval, 1.18 to 2.49) for subjects 35 to 44 years old to 9.01 (5.86–13.89) for subjects 65 to 74 years old (16).

Regarding sex, significantly more recession (facial sites: baseline to 1 year) was observed in males than in females only during the first year after surgery. The periodontal literature on risk factors for gingival

TABLE 6. Mean Changes in Clinical Attachment Level (n = 186) from Baseline to 1 Year (Δ 0–1), from 1 to 5 Years (Δ 1–5), and from Baseline to 5 Years (Δ 0–5)

Variables	Subcategories	n	Δ 0–1 facial	Δ 0–1 lingual	Δ 1–5 facial	Δ 1–5 lingual	Δ 0–5 facial	Δ 0–5 lingual
All patients	—	186	0.20	0.12	0.07	0.08	0.27	0.20
Gender	Female	102	0.15	0.15	0.10	−0.01	0.25	0.13
	Male	84	0.25	0.09	0.04	0.20	0.28	0.29
Age	< 45 years	65	0.27	0.12	−0.09[a]	0.09	0.19	0.22
	≥ 45 years	121	0.15	0.12	0.16[a]	0.07	0.31	0.19
Smoking	No	135	0.19	0.16	0.04	−0.05[b]	0.23	0.10[c]
	Yes	51	0.21	0.03	0.15	0.43[b]	0.36	0.46[c]
Tooth	Maxillary anterior teeth*	58	0.26	0.12	−0.07[d]	−0.02	0.18	0.10
	Maxillary premolars	34	0.00	−0.13	0.06[d]	0.00	0.06	−0.13
	Maxillary molars	27	−0.07	0.22	0.07[d]	−0.20	−0.01	0.02
	Mandibular anterior teeth*	6	0.47	0.67	0.36[d]	0.08	0.83	0.75
	Mandibular premolars	11	0.03	0.27	0.21[d]	−0.05	0.24	0.23
	Mandibular molars	50	0.41	0.14	0.18[d]	0.43	0.59	0.57
Restoration	Crown	133	0.19	0.09	0.05	0.10	0.24	0.19
	Filling	32	0.18	0.34	0.29	0.08	0.46	0.42
	None	21	0.25	0.00	−0.12	−0.05	0.13	−0.05
Incision	Intrasulcular	112	0.33[e]	0.24[f]	0.04	0.08	0.37	0.32
	Papilla-base	36	0.14[e]	−0.01[f]	0.04	0.04	0.18	0.03
	Submarginal	38	−0.14[e]	−0.11[f]	0.20	0.12	0.05	0.01
Healing	Healed	158	0.18	0.07	0.03[g]	0.05	0.21[h]	0.12[i]
	Not healed	28	0.28	0.43	0.30[g]	0.23	0.58[h]	0.66[i]

Positive values = loss of clinical attachment.

Negative values = gain in clinical attachment.

Identical superscripts denote statistically significant differences across subcategories per variable: $P < .05^{b,c,d,f,g,h,i}$; $P < .01^{a}$; $P < .001^{e}$.

*Anterior teeth = incisors and canines.

recession has reported that males have more gingival recession than females (15, 17–19).

Regarding smoking, according to the study by von Arx et al (2), the smoking habit of the patient did not influence the changes in periodontal parameters after apical surgery during a follow-up period of 1 year. This finding was confirmed in the present study, showing no significant differences for changes in PD, GM, and CAL when smokers were compared with nonsmokers for the first year after surgery. However, smokers had significantly more CAL loss (lingual sites: 1 to 5 years and baseline to 5 years) and increase of PD (facial sites: baseline to 5 years; lingual sites: 1 to 5 years and baseline to 5 years) compared with nonsmokers, showing a negative influence of smoking over the longer observation period. This finding is in line with data from the periodontal literature. Smokers were found to have higher prevalence and extent of attachment loss than nonsmokers (20). PD, gingival recession, and CAL were reported to be greater in smokers than in former smokers or nonsmokers (21).

With regard to the type of treated tooth, significant differences were only found for changes in PD and CAL at facial sites from 1 to 5 years but not for the first year after surgery. The greatest changes were noted in mandibular anterior teeth, but this group only accounted for six teeth (out of a total of 186 treated teeth). Regarding the type and presence of a restoration margin, only changes in PD were found to be significant for this variable (limited to facial sites from baseline to five years). Treated teeth without a restoration margin at the gingival level showed less recession and less attachment loss either at facial or lingual sites from baseline to 5 years and from 1 to 5 years, respectively. However, the changes in GM and CAL across the subcategories of the variable "restoration" were not significantly different; this is in accordance with a previous study (2). In the periodontal literature, the level of a crown or filling margin in relation to the gingival margin has been shown to influence further changes in the marginal tissues. When a restoration margin was located subgingivally, this resulted in significantly more gingival recession and loss of attachment compared with a supragingival location (22) (ie, over an observation period of 5 years, an average loss of attachment of 1.2 mm was seen in teeth with the crown margins located subgingivally versus 0.6 mm of attachment loss in teeth with a supragingival location). In contrast, Reichen-Graden and Lang (23) found no statistically significant difference in continuous loss of periodontal support when comparing abutment teeth with homologous contralateral uncrowned control teeth.

Conclusions

Apical surgery resulted in gingival recession and a loss of clinical attachment during the first year after surgery (these changes proved to be significant at facial sites); the mean recession was 0.29 mm and the mean loss of attachment was 0.20 mm. No significant changes in mean values of PD, GM, and CAL were observed between 1 year and 5 years after surgery for all teeth. Various covariables were found to influence the changes in the studied periodontal parameters; during the first year, the major factor affecting changes in GM and CAL was the type of incision technique, whereas for the longer study period up to 5 years, the periodontal parameters were mainly influenced by the patients' age and smoking habit as well as by the type of periapical healing.

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