

Article original

Success rate and recurrence frequency of periapical surgery: prospective study on 132 cases

Alp Alantar^{1,*}, Candice Bloud², Jean-Marc Galéazzi¹, Marc Baranes³, Gérard Lévy⁴, David Chapireau⁵, Nadia Benlagha⁶, Louis Maman⁷

¹ Max Fourestier Hospital, 92000 Nanterre, France

² Private practice, 75016 Paris, France

³ Ivry sur Seine Hospital, 94200 Ivry sur Seine, France

⁴ Endodontic Dentistry department, René Descartes University, 75005 Paris, France

⁵ St Edmund's College, CB3 0BN Cambridge, UK

⁶ André Grégoire Hospital, 93100 Montreuil, France

⁷ Oral Surgery Department, René Descartes University, 75005 Paris, France

(Received 26 September 2009, accepted 18 November 2009)

Abstract – Objectives: Primary aim is to quantify the success rate of periapical surgery. Secondary objectives include the determination of the histological nature of the lesions, and the incidence of the different teeth on which this surgery is performed.

Study design: This is a prospective cohort study conducted in one centre. The same operator following a standardized surgical protocol performed all surgeries. Follow-up (including clinical examination and periapical X-ray) was conducted at day 7, and months 6, 12 and 18. Statistical analysis included determination of the mean, standard deviation and paired two-tailed Student's t-test, for each of the variables.

Results: 132 periapical surgeries were performed on 114 patients. Success and failure rate at 18 months, are 90%, and 6%, and uncertain in 4%. Histopathology confirmed that 72% of the lesions were granulomas, and 28% cysts. Periapical surgery pertains mostly to maxillary (70%) and posterior teeth (70%).

Conclusion: Prognosis of conventional periapical surgery is very good. Failure rate peaks at 7 months, written informed consent is paramount.

Key words:

radicular cyst /
apicoectomy /
prospective study /
wound healing /
periapical periodontitis /
retrograde obturation

A radiolucent apex after endodontic treatment is a common finding with up to 45% of the treated teeth in certain studies [1, 2]. These lesions can be found during a routine check-up, or during an emergency appointment when associated with pain. As orofacial pain is ascribed to periapical abscesses in 25% of the patients [3], these periapical radiolucencies, in the context of periapical surgery, can be a diagnostic challenge. Periapical abscesses are the consequence of a bacterial infection of the root canals [4]. Treatment classically consists of the elimination of necrotic and infected tissue, followed by obturation of the root canal system and a sealed restoration of the crown. Periapical surgery is indicated when root canal retreatment has failed or is contraindicated [4]. An osteo-mucoperiosteal flap followed by the appropriate osteotomy allows access to the apex of the tooth. The lesion is removed and the root canal system sealed [4]. Success rates reported vary between 40% [5] and 97% [6].

The main objective of this study is to assess the success rate of periapical surgery using a standardized protocol. Secondary objectives include the determination of the histological appearance of the lesions (granulomas or cysts), the incidence of the different teeth on which this surgery is performed, and the recurrence frequency.

Material and methods

Inclusion criteria

Patients included were male and female, without any age limit, referred for periapical surgery between January 2003 and June 2006 (follow-up period from 2003 to 2008) on any endodontic treated tooth, which showed one or more periapical lesion. Endodontic retreatment was either contraindicated or had failed.

* Correspondence: alpantar@wanadoo.fr

Exclusion criteria

Exclusion criteria are: (i) medical contraindication to oral surgery, (ii) incomplete tooth fracture (presence of a solitary buccal pocket or a gingival margin fistula or a lateral radiolucency) or chamber floor perforation and (iii) alveolar bone loss greater than 50% of the apex/cervical tooth length [7–10].

Data collected

Data collected for each patient is age, gender, past medical history and ongoing dental treatments. The position of the tooth is noted: anterior (incisors, canines) or posterior (premolar, molar), maxillary or mandibular, along with the relevant quadrant. The Technical Standard Root filling (TSR) index [11] (Table 1A), the presence of an inlay-core and of a crown is assessed on an X-ray. Histopathological diagnosis, when the lesion was large enough to undergo analysis, was also recorded. Recurrence time after the surgery is noted in weeks.

Appraisal criteria

Clinical criteria include presence of a fistula and/or a pain on percussion. Radiological criteria are the presence or absence of a periapical translucency.

Statistical analysis

For each outcome (success, uncertain healing, failure) this study reports the mean age of the patient, the relative importance of each type of lesion, and when appropriate the mean recurrence time. A paired two-tailed Student t-test was used when a statistically significant difference was found (p value = 0.05).

Standardized surgical protocol

Every patient was operated by the same oral surgeon, using the same protocol. Patients are taught oral hygiene techniques, scale and polish is performed by the patient's dentist. In order to minimize short-term post-treatment operative complication, preoperative medication included (i) amoxicillin (1 g bd for 6 days, *per os*) or, when the history of an allergy is reported, a macrolide (erythromycin 1g bd for 6 days, *per os*) (ii) prednisolone (1 mg/kg bd for 3 days, *per os*) and (iii) tramadol (50 mg qds for 3 days, *per os*). The procedure is performed as an outpatient under local anaesthesia (articaine 4% with adrenaline/epinephrine 1/200 000). An intrasulcular triangular full thickness flap [12], or submarginal flap (Ochsenbein-Luebke) if aesthetic consideration warrants

it, is raised [13, 14]. An osteotomy is performed (with irrigation) with a spherical bur in a high-speed straight or contra-angle handpiece to access the relevant apex. The size of the osteotomy is sufficient to excise the lesion and for the retrograde obturation. It is however kept minimal to improve healing [4, 15–18]. A bone scraper is used to excise the apical lesion. The surgical specimen is fixated in buffered formol solution and sent to histopathology. The apical 3 mm is sectioned [7, 19] with a Zekrya bur in a turbine under a magnifying loupe.

The canal is prepared over 2 to 4 mm with an ultrasonic device [4, 8, 9, 21, 21–24]. The canal and the cavity is dried, and haemostasis is achieved using an oxycellulose gauze (Surgicel®). Obturation was completed with a zinc oxide-eugenol with polymer reinforcement (Intermediate Reinforcement Material – IRM®) [18, 24, 25]. When surgical re-intervention was necessary, after failure of a first periapical surgery, Proroot Mineral Trioxide Aggregate (MTA®) was used instead of IRM® to obturate the canal and, crown/root ratio allowing, the apex was resected of a further millimetre [25, 26].

In case of anterior teeth for which the endodontic treatment was deemed satisfactory clinically (probing) and radiologically (Type A or C), the apex was simply burnished using a ball burnisher (Wallis®) [20, 27, 28]. Indirect vision was achieved with surgical micro-mirrors. The flap is repositioned in its original location and sutured with absorbable Vicryl® 3.0 using simple interrupted stitches [29].

Evaluation

Postoperative follow-up starts at day 7, and includes a clinical examination and a periapical X-ray of the tooth. The aforementioned appraisal criteria are noted then, and at months 6, 12 and 18 [10]. Failure is defined as pain on percussion, or the presence of a fistula. The X-ray is interpreted by the surgeon. Results fall into following three categories [9, 17, 30, 31]:

“Success”: no clinical symptoms, and no periapical radiolucency (Fig. 1B);

“Uncertain healing”: no clinical symptoms albeit a periapical radiolucency (Fig. 2B);

“Failure”: clinical symptoms with periapical radiolucency.

In this study, any tooth that was extracted or whose root had to be resected albeit initial antibiotic treatment and/or surgical re-intervention with MTA® obturation, was classified as a “failure”.

Results

Success rate after initial treatment (IRM® or simply burnished apices)

One hundred and thirty two surgeries followed-up from 2003 to 2008 were performed in the index period (January

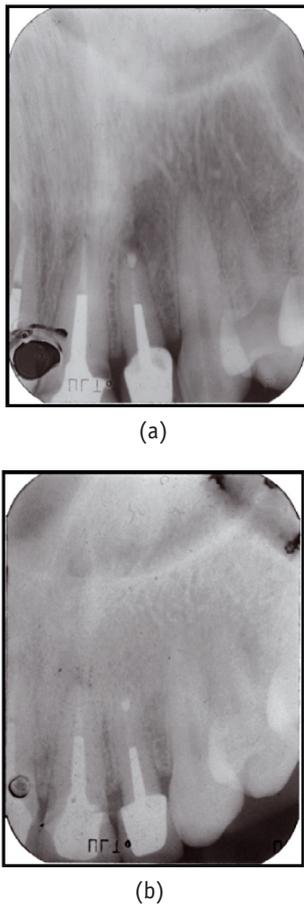


Fig. 1. (a) Periapical X-ray of tooth 22 taken at day 7. (b) Periapical X-ray of tooth 22 taken at 18 months. No clinical symptoms and no periapical radiolucency. This outcome was judged "successful" (case 30).

2003 to June 2006) on 114 patients (49 males and 65 females) aged 15 to 79 years (medium age was 46 ± 12). Simple brushing was performed in 8.5% (11/132) of the apical surgeries and no failure was noticed for these patients. Success rate after initial treatment (IRM® or simply burnished apexes) (Fig. 4) at one year, is 90% (119/132). Failure rate is 6% (8/132) and the healing is uncertain in 4% (5/132); 1,75% (2/114) of the patients were lost during follow-up.

Histopathology

Seventy percent of the operated lesions were sent to histopathology, the rest (30%) being either too small or non-cleavable. The number of specimen per tooth was 2 ± 1 mm for a length of 5 ± 2 mm for the largest one. Most of the lesions were granulomas (72%), the rest being cysts (28%). As for the cysts, 88% showed a continuous squamous epithelium, and 12% islands there of. Polymorphonuclear neutrophils were more commonly found in granulomas (76%) as compared to

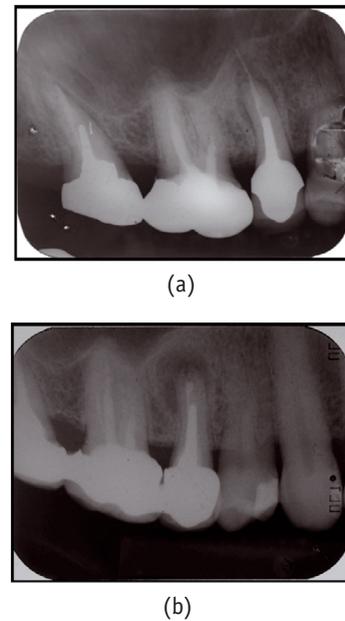


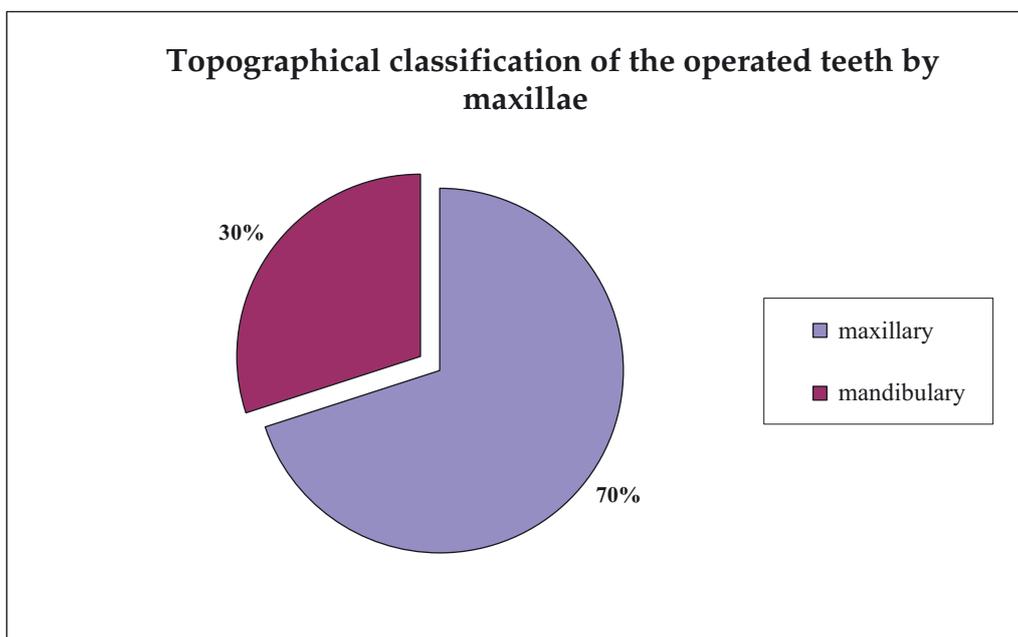
Fig. 2. (a) Periapical X-ray of tooth 15 taken at day 7. (b) Periapical X-ray of tooth 15 taken at 18 months, re-obtreated with MTA® at 9 months after failure of the initial treatment. A periapical radiolucency is visible, albeit no clinical symptoms. This outcome was judged "uncertain healing" (case 57).

cysts (32%). Surgical success rate is higher for cysts than for granulomas, 96% and 82.5% respectively.

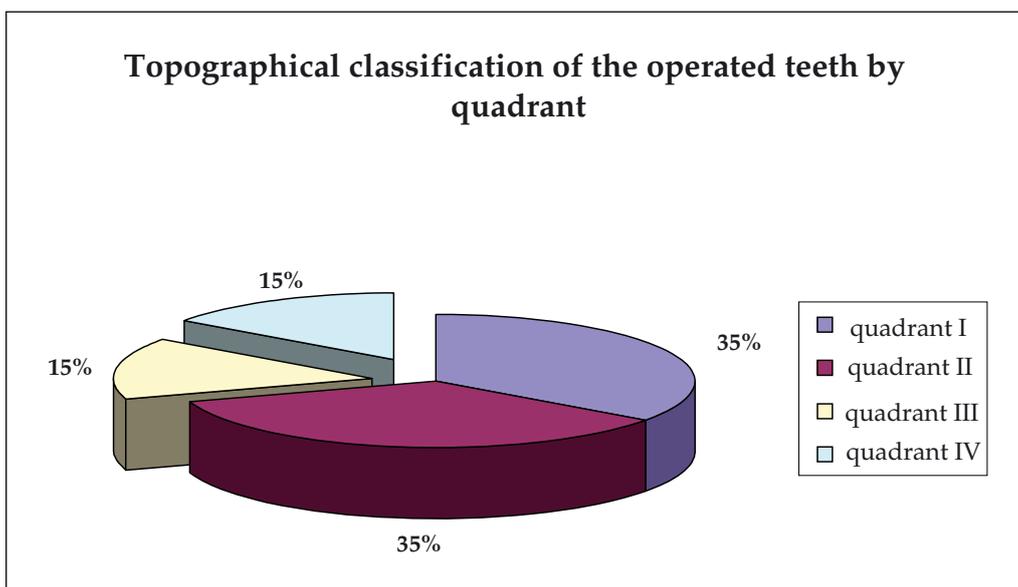
Topography

The indication of periapical surgery pertains mostly to maxillary (70%) (Fig. 3A) and posterior (70%) teeth (premolars: 34% and molars 36%). Thirty percent were anterior teeth (incisors: 28%, canines: 2%). No statistical difference was found between quadrants 1/2 and 3/4 (35%, 35%, 15% and 15% for respectively quadrants 1, 2, 3, and 4) (p value = 0.5) (Fig. 3B).

Seventy seven percent of the teeth were crowned with a ceramo-metallic crown, 11% had a full-veneer crown, 4.3% had a temporary crown, 7,7% had been restored with an amalgam. An inlay-core protected the canal system in 41.3% of the teeth. Each tooth was scored according the TSR classification (Technical Standard of Root filling) [11]. Results are presented in Table 1B and 1C. Thirty seven percent of the patients were medicated for different conditions (diabetes, hypertension, hypercholesterolemia, thyroid disease, rheumatoid arthritis, depression, candidosis, dysmenhoreria. . .). Patients who had a medical contra-indication to oral surgery were excluded from this study. In contrast to Von Arx et al.'s study [29], drainage was not indicated in any of our patients as none was referred with a collected lesion.



(a)



(b)

Fig. 3. (a) Topographical classification of the operated teeth by maxillae. (b) Topographical classification of the operated teeth by quadrant.

Recurrences

Recurrence occurred at 28 ± 23 weeks (earliest: 5 weeks, latest: 51 weeks). All of these teeth had an endodontic treatment of type B, C, D, E or F (Ödesjö et al.'s classification [11]) (Table 1A) and 91% clinically had a good cervical marginal adaptation. Success rate of surgical re-intervention at 12 months was 30%. Either the reminding teeth had to be extracted, or the relevant roots amputated.

Postoperative complications

Common short-term complications were reported in 16.3% of the patients and include rhinorrhea, fistula, oedema, or moderate/severe pain (above 7/10 on the analogue visual scale). The latter prompted prescription of opioids, as recommended by the WHO pain management ladder (step 3 in this case). One patient presented with a transient mental nerve paraesthesia following surgery on a mandibular lateral incisor.

Table 1A. Apical lesions classified according to their Technical Standard of Root filling (TSR) index [11].

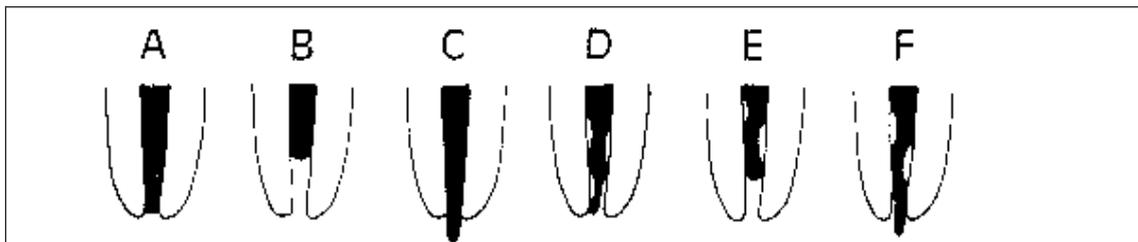


Table 1B. Apical lesions classified according to the density of the material and the root fillings ending [11].

Catégorie	Description
A	Proper obturation 2 mm from apex
B	Proper obturation > 2 mm from apex
C	Proper obturation over-filling
D	Improper obturation ≤ 2 mm from apex
E	Improper obturation > 2mm from apex
F	Improper obturation over filling

Table 1C. Prevalence of apical lesions (confirmed on X-ray) of the present study.

Indice TSR	A	B	C	D	E	F
Prevalence	13.4%	39.7%	17%	6.6%	17.6%	5.7%

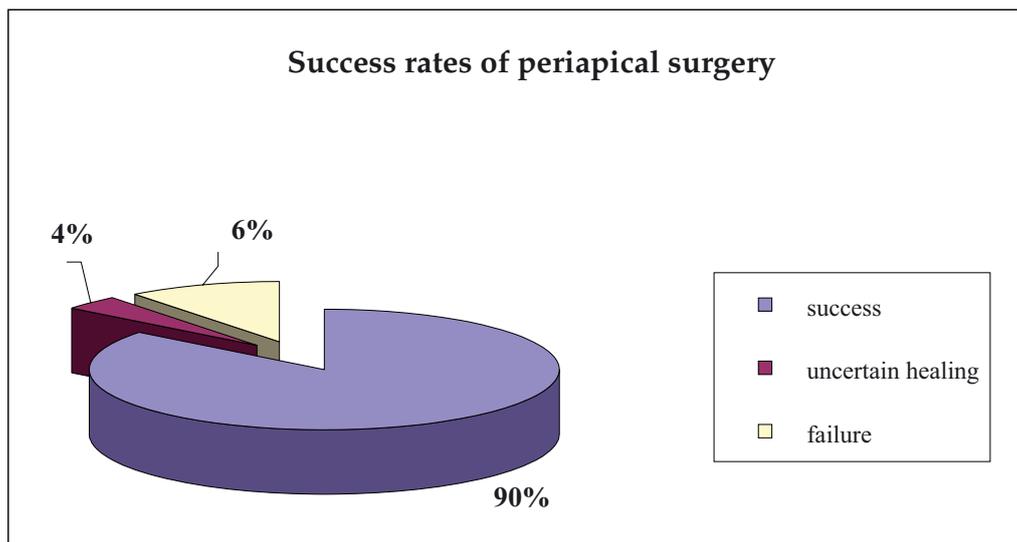


Fig. 4. 18 month overall success rate for initial treatment (IRM®) including simply burnished apices.

Discussion

Epidemiology

Most studies measuring success rates of conventional periapical surgery are on small cohorts, case control studies (level 1C of the Oxford Centre for evidence-based medicine levels of evidence) or case reports (level 5 of the Oxford Centre for

evidence-based medicine levels of evidence) [32,33]. Studies furthermore rarely distinguish between the cysts and granulomas [34,35].

Here, women are overrepresented (58.3% – female/male ratio: 1.4). Although female constituted a majority of the patients, the female to male ratio was closer to one (F/M = 1.4) here than in the studies conducted by Oginni and Olusile [35] and Zuolo et al. [22] (F/M ratio being respectively 1.7 and

3.5). The greater prevalence of maxillary teeth (70%) over mandibular ones was also a finding of the two aforementioned studies.

The greater complexity of the root system of premolars and molars explains the greater failure rate of endodontic treatment on these teeth [34], and their relative incidence in periapical surgery.

Protocol

Like in Von Arx et al.'s study [29] painkillers and chlorhexidine digluconate 0.1% mouthwash were systematically prescribed here. In contrast to these authors, antibiotics (for 8 days) and steroids (for 3 days) were prescribed to every patient to minimize short-term postoperative complications.

The size of the osteotomy is kept to minimal to improve healing [9]. The 3 mm section of the apex will eliminate 98% of the apical ramifications and 93% of the lateral canals [36]. A simple burnish of the root, without resection or retrograde obturation, was only performed on anterior teeth whose endodontic treatment was satisfactory. Apices of molars and premolars with their complex root system (isthmuses and double canals) should all be resected and be obturated [37].

Local haemostasis is achieved by two means: (i) use of an anaesthetic agent containing adrenaline (ii) the use of oxycellulose gauze (Surgicel®). Both of these means improve outcome [36].

Results

Success, uncertain healing and failure rates

The overall success rate for initial treatment (IRM®) including simply burnished apices is 90%, hereby achieving similar rates than Tashieri et al. in 2005 [9] (91.3% success rate at one year). Combined success/uncertain healing rates (90% and 4%) are similar to those published by Tashieri et al. [9] (respectively 91.3% and 2.17%) and Maddalone and Gagliani [8] (respectively 92.5% and 3.3%). In the studies that used IRM® the success rate was noticeably lower with success rates ranging from 65% to 76% at 12 months [23,27]. These results are in line with those of studies conducted with any material (ranging from 40% [5] to 97% [6]), and it can therefore be concluded that, at one year, IRM® is neither better nor worse than any other material. Success rates however subsequently falls for amalgam and glass ionomer cement with a 4-year success rate ranging from 59% [38] to 70% [39]. Long-term prognosis is beyond the scope of this study.

In this study the overall success for IRM® (90%) was similar to thus of Saunders's study [40], using MTA® following micro-surgical technique (88,8%). More over, the randomized trial by Chong et al. [25] showed that the success rates achieved with IRM® and MTA® were not statistically different, albeit a marked price difference. For those reasons, IRM® was

used in the first instance here. Nevertheless root end preparation with ultrasonic retrotips and use of the MTA® under the microscope is indicated in anatomically complex cases 41.

IRM® was used here in the first, and it showed greater [42] or similar [27] efficacy to amalgam. Different materials have been used in other studies [6-8, 29, 43, 44] such as Super EBA® (ethoxybenzoic acid). Case reports have been published on the usage of gutta-percha [45] or using CO₂ lasers [46].

This study achieves similar results as the others who used ultrasonic endodontic instruments for which success rates are all above 90% [9, 29, 43]. Testori et al. [47] showed that he achieved better results with ultrasonic endodontic instruments than with rotating ones (85% and 68% respectively). These results are explained by an easier access of ultrasonic instruments to the cavity as compared with traditional ones, especially for posterior teeth. Furthermore they allow for deeper apical cavities, whose walls will remain parallel, respect the axis of the tooth [22, 48], and access isthmuses [49]. The last advantage is to allow for a smaller osteotomy, thereby improving healing [15, 16, 18].

This study also achieves similar results as those who used ultrasonic instruments under a microscope, also 90% on average [4]. The failure rates of this study and of those published by Tashieri et al. [9] are similar (6% and 6.51% respectively). Failure rate of re-intervention was however quite high here, 70% at one year as compared to 23% at five years for Gagliani et al. [50]. This may be explained by two factors: (i) smaller number of re-interventions in this study (12 as opposed to 69 for Gagliani et al. [50]) and (ii) different materials used (IRM® here, SuperEBA® with Gagliani et al. [50]).

Complications and recurrence time

Short-term complications such as oedema and pain have previously been reported in the literature [37]. Recurrence occurred at 28 ± 23 weeks (earliest: 5 weeks, latest: 51 weeks), which is in line with Cheung and Lam's findings (12 to 24 weeks) [51]. This delay should teach patience, and guard towards reassuring the patient too soon regarding possible success of the surgery.

Histopathology

In this study, most of the lesions were granulomas (72%), the rest being cysts (28%). These findings are similar to those by Sanchis et al. [34] (respectively 83.3 and 16.7%), and Nair et al. [52-54] (respectively 73% and 15%). These values differ however from those reported by Ogini and Olusile [35] (respectively 33.3% and 43.9%). This difference might be partially explained by the fact that in this latter study histological results were divided into three group (and not two), the last one being "chronic non specific inflammation" (22.8%).

Success rates for cysts is statistically higher than for granulomas (96% vs. 82.5%, *p* value 5%), a finding shared with

Ogini and Olusile [35] (33.3% vs. 24.6%). This difference in success rates might reflect the relative easiness to remove a cyst, which present with an epithelial wall, compared to granuloma, which do not. Differences in success rates also reflect different surgical technique [8, 33].

Conclusion

Periapical surgery warrants a thorough history, clinical, and radiological examination. Periapical surgery is the last therapeutic option after endodontic treatment has failed to save the relevant tooth/root. Strict surgical protocols, the use of ultrasonic devices and of binoculars concur to a good prognosis. A 18 month success rate of 90% reflects those already reported in the literature. As the mean recurrence time is 7 months, the surgeon should be cautious regarding hasty reassurance, and observe a strict follow-up. The recurrence time and success rate are significantly lower in the case of re-intervention. After a second failure, root amputation or extraction of the tooth is warranted, leading to a change in the prosthetic treatment plan. Written informed consent is paramount in this context.

References

- Dugas NN, Lawrence HP, Teplitsky PE, Pharoah MJ, Friedman S. Periapical health and treatment quality assessment of root-filled teeth in two Canadian populations. *Int Endod J* 2003;36:181-92.
- Friedman S. Considerations and concepts of case selection in the management of post-treatment disease (treatment failure). *Endod Topics* 2002;1:54-78.
- Ahossi V, Devoize L, Tazi M, Perrin D. Urgences odontologiques au centre hospitalier universitaire de Dijon. Analyse de 12 mois d'activité. *Clinic* 2002;23:165-70.
- Zesis A, Lin S, Fuss Z. Endodontic surgery (apicoectomy)-success rate of more than 90% using dental operating microscope and ultrasonics tips. *Refuh Hapeh Vehashinayim* 2005;22:33-41
- Friedman S, Lustmann J, Shaharabany V. Treatment results of apical surgery in premolar and molar teeth. *J Endod* 1991;17:30-3.
- Rubinstein RA, Kim S. Short-term observation of the results of endodontic surgery with the use of a surgical operation microscope and Super-EBA as root-end filling material. *J Endod* 1999;25:43-8.
- Von Arx T, Kurt B. Root-end cavity preparation after apicectomy using a new type of sonic and diamond surfaced retrotip: a 1-year follow-up study. *J Oral Maxillofac Surg* 1999;57:656-61.
- Maddalone M, Gagliani M. Periapical endodontic surgery : a 3 year follow-up study. *Int Endod J* 2003;36:193-8.
- Taschieri S, Del Fabbro M, Testori T, Francetti L, Weinstein R. Endodontic surgery with ultrasonic retrotips: one-year follow-up. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2005;100:380-7.
- Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. *J Endod* 1999;25:506-8.
- Ödesjö B, Helldén L, Salonen L, Langeland K. Prevalence of previous endodontic treatment, technical standard and occurrence of periapical lesions in a randomly selected adult, general population. *Endod Dent Traumatol* 1990;6:265-72.
- Bensoussan D. Vers un abord atraumatique des tissus parodontaux en endodontie chirurgicale. *Réal Clin* 1996;7:353-65.
- Gutmann JL, Harrison JW. *Surgical endodontics* (468 p.). Blackwell scientific publications, Boston, 1991.
- Von Arx T, Vinzens-Majaniemi T, Bürgin W, Jensen SS. Changes of periodontal parameters following apical surgery: a prospective clinical study of three incision techniques. *Int Endod J* 2007;40:959-69.
- Hirsh JM, Ahlström U, Heyden G. Periradicular surgery. *Int J Oral Surg* 1979;8:173-85.
- Mikkonen M, Kullaa-Mikkonen A, Kotilainen R. Clinical and radiologic re-examination of apicoectomized teeth. *Oral Surg Oral Med Oral Pathol* 1983;55:302-06.
- Von Arx T, Hanni S, Jensen SS. Correlation of bone defect dimensions with healing outcome one year after apical surgery. *J Endod* 2007;33:1044-48.
- Grung B, Molven O, Halse A. Periapical surgery in a Norwegian county hospital: follow-up findings of 477 teeth. *J Endod* 1990;16:411-7.
- Von Arx T, Kurt B, Ilgenstein B, Hardt N. Preliminary results and analysis of a new set of sonic instruments for root end cavity preparation. *Int Endod J* 1998;31:32-8.
- Wang N, Knight K, Dao T, Friedman S. Treatment outcome in endodontics. The Toronto Study. Phases I and II : apical surgery. *J Endod* 2004;30:751-61.
- Pashley DH. Smear layer : physical considerations. *Oper Dent (Suppl)* 1984;3:13-29.
- Wuchenich L, Meadows D, Torabinejad M. A comparison between two root-end preparation techniques in human cadavers. *J Endod* 1994;20:279-82.
- Engel TK, Steiman HR. Preliminary investigation of ultrasonic root end preparation. *J Endod* 1995;21:443-5.
- Zuolo ML, Ferreira MO, Gutmann JL. Prognosis in periradicular surgery: a clinical prospective study. *Int Endod J* 2000;33:91-8.
- Chong BS, Pitt Ford TR, Hudson MB. A prospective clinical study of Mineral Trioxide Aggregate and IRM when used as root-end filling materials in endodontic surgery. *Int Endod J* 2003;36:520-6.
- Torabinejad M, Hong CU, McDonald F, Pitt Ford TR. Physical and chemical properties of a new root-end filling material. *J Endod* 1995;21:349-53.
- Rapp EL, Brown CE Jr, Newton CW. An analysis of success and failure of apicoectomies. *J Endod* 1991;17:508-12.
- August DS. Long-term, postsurgical results on teeth with periapical radiolucencies. *J Endod* 1996;22:380-3.
- Von Arx T, Gerber C, Hardt N. Periradicular surgery of molars: a prospective clinical study with a one-year follow-up. *Int Endod J* 2001;34:520-5.
- Rud J, Andreasen JO, Jensen MJE. Radiographic criteria for the assessment of healing after endodontic surgery. *Int J Oral Surg* 1972;1:195-214.
- Ericson S, Finne K, Persson G. Results of apicoectomy of maxillary canines, premolars and molars with special reference to orofacial communication as a prognostic factor. *Int J Oral Surg* 1974;3:386-93.

32. Niederman R, Theodosopoulou JN. A systematic review of in vivo retrograde obturation materials. *Int Endod J* 2003;36:577-85.
33. Mead C, Javidan-Nejad S, Mego ME, Nash B, Torabinejad M. Levels of evidence for the outcome of endodontic surgery. *J Endod* 2005;31:19-24.
34. Sanchis JM, Penarrocha M, Bagan JV, Guarinos J, Vera F. Incidence des kystes radiculaires dans une série de 125 lésions périapicales chroniques. *Rev Stomatol Chir Maxillofac* 1997;98:354-8.
35. Oginni AO, Olusile AO. Follow-up study of apicectomised anterior teeth. *SADJ* 2002;57:136-40.
36. Kim S, Pecora G, Rubinstein R. Comparison of traditional and microsurgery in endodontics. (pp 5-11) In: *Color atlas of microsurgery in endodontics*. Kim S, Pecora G, Rubinstein R, eds. Saunders, Philadelphia, 2001.
37. Kim S, Kratchman S. Modern endodontic surgery concepts and practice: a review. *J Endod* 2006;32:601-23.
38. Jesslén P, Zetterqvist L, Heimdahl A. Long-term results of amalgam versus glass ionomer cement as apical sealant after apicectomy. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1995;79:101-3.
39. Rahbaran S, Gilthorpe MS, Harrison SD, Gulabivala K. Comparison of clinical outcome of periapical surgery in endodontic and oral surgery units of a teaching dental hospital: a retrospective study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001;91:700-9.
40. Saunders WP. A prospective clinical study of periradicular surgery using mineral trioxide aggregate as a root-end filling. *J Endod* 2008;34:660-5.
41. Von Arx T, Jensen SS, Hänni S. Clinical and radiographic assessment of various predictors for healing outcome 1 year after periapical surgery. *J Endod* 2007;33:123-8.
42. Dorn SO, Gartner AH. Retrograde filling materials: a retrospective success-failure study of amalgam, EBA, and IRM. *J Endod* 1990;16:391-3.
43. Von Arx T. Failed root canals: the case for apicoectomy (periradicular surgery). *J Oral Maxillofac Surg* 2005;63:832-7.
44. Sumi Y, Hattori H, Hayashi K, Ueda M. Ultrasonic root-end preparation: clinical and radiographic evaluation of results. *J Oral Maxillofac Surg* 1996;54:590-3.
45. Sauveur G, Roth F, Sobel M, Boucher Y. Surgical treatment of a periradicular lesion on an invaginated maxillary lateral incisor (dens in dente). *Int Endod J* 1997;30:145-9.
46. Bader G, Lejeune S. Prospective study of two retrograde endodontic apical preparations with and without the use of CO2 laser. *Endod Dent Traumatol* 1998;14:75-8.
47. Testori T, Capelli M, Milani S, Weinstein RL. Success and failure in periradicular surgery: a longitudinal retrospective analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999;87:493-8.
48. Mehlhaff DS, Marshall JG, Baumgartner JC. Comparison of ultrasonic and high-speed-bur root-end preparations using bilaterally matched teeth. *J Endod* 1997;23:448-52.
49. Hsu YY, Kim S. The resected root surface. The issue of canal isthmuses. *Dent Clin North Am* 1997;41:529-40.
50. Gagliani MM, Gorni FG, Strohmenger L. Periapical resurgery versus periapical surgery: a 5-year longitudinal comparison. *Int Endod J* 2005;38:320-7.
51. Cheung LK, Lam J. Apicectomy of posterior teeth—a clinical study. *Aust Dent J* 1993;38:17-21.
52. Nair PN. New perspectives on radicular cysts: do they heal? *Int Endod J* 1998;31:155-60.
53. Nair PN. Non-microbial etiology: foreign body reaction maintaining post-treatment apical periodontitis. *Endod Topics* 2003;6:114-34.
54. Nair PN, Pajarola G, Schroeder HE. Types and incidence of human periapical lesions obtained with extracted teeth. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1996;81:93-102.