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Retrograde root canal retreatment with pre-bent ultrasonic files. A retrospective outcome study

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Abstract

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Aim To assess retrospectively the clinical and radiographic outcomes of retrograde root canal retreatment (RRR) and to identify possible prognostic factors that may affect the outcome.

Methodology Clinical records and radiographs were collected from patients who had undergone RRR between 2009 and 2016 and had a 1-year follow-up. All surgical procedures were performed by a single endodontist. The RRR technique involved minimal root-end resection and maximal length retrograde preparation using pre-bent ultrasonic files. Outcomes were categorized as complete, incomplete, uncertain or unsatisfactory healing based on clinical and radiographic findings. The complete and incomplete healing cases were pooled and considered as successes, while uncertain and unsatisfactory cases were considered failures. Prognostic factors were analysed using univariate analysis and multivariate logistic regression.

Results In total, 575 patients with 721 teeth were included. The overall success rate was 91.8%. None of the prognostic factors (including age, gender, size of periapical radiolucency and isthmus presence) had a significant influence on the outcome ($P > 0.05$). Univariate analysis revealed tooth type had a significant influence on outcome ($P = 0.008$) with mandibular incisors having a significantly lower success rate (71.4%). Multivariate analysis using logistic regression revealed that the only variable with a significant association to the outcome was retrograde preparation length ($P = 0.016$, odds ratio = 1.299 (1.050, 1.607), C.I. = 95%)), i.e. the longer the retrograde preparation, the better the outcome.

Conclusions Retrograde root canal retreatment was successful in 91.8% of cases. This predictable success rate was achieved while minimizing root-end resection and maximizing retrograde canal preparation length.

Keywords: minimal resection, outcome study, retrograde preparation, retrograde root canal retreatment, ultrasonic files.

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Introduction

One of the major factors associated with post-treatment endodontic disease is the persistence of microbial infection in the root canal system and/or the periradicular area (Nair *et al.* 1990, Lin *et al.* 1992). To achieve healing of periapical lesions, disinfection of the entire canal during root canal retreatment is attempted, followed by root canal filling. If periradicular pathosis exists and root canal retreatment is impractical or would not achieve suitable results, endodontic microsurgery is indicated (Johnson & Fayad 2016). Endodontic microsurgery should be considered an extension of nonsurgical treatment because the underlying aetiology of the disease process and the objectives of treatment are the same (Johnson & Fayad 2016). Therefore, the principles of root canal retreatment should apply to the retrograde surgical approach, i.e. removal of microorganisms and debris from the root canal system, shaping of the

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walls to facilitate cleaning and subsequent filling of the root canal space.

Modern endodontic microsurgery involves a 3-mm apical root resection followed by a 3-mm root-end preparation and filling (Kim & Kratchman 2006). The rationale being to remove lateral canals and apical ramifications (Kim *et al.* 2001), and to achieve an apical seal to minimize leakage (Gilheany *et al.* 1994, Carr 1997).

In certain clinical situations, adherence to the aforementioned technique might not be feasible or practical (Von Arx *et al.* 2015). In cases of long posts terminating in the apical third, a 3-mm resection might leave insufficient root length for root-end preparation and filling. Furthermore, in cases of relatively short roots, a 3-mm resection might impair the crown-to-root ratio. In such cases, a more conservative resection may be preferable. A thorough examination of the literature revealed that the 3-mm root-end preparation is aimed at creating appropriate space for root-end filling in an attempt to remove irritants and prevent leakage, with no attempts made to clean the root canal system further coronally (Mattison *et al.* 1985, Vertucci & Beatty 1986, Edmunds & Thirawat 1989, King *et al.* 1990, Yoshimura *et al.* 1990, O'Connor *et al.* 1995, Forte *et al.* 1998, Gondim *et al.* 2003, 2005).

The purpose of this retrospective study was to assess the clinical and radiographic outcomes of retrograde root canal retreatment involving minimal root-end resection and maximal length retrograde root canal preparation and to identify possible prognostic factors that may affect the outcome.

Materials & methods

This study was approved by the Institutional Ethics Committee (IEC No. 72.18).

Case selection

An evaluation of all patients treated in a University setting and a private clinic, between January 2009 and December 2016, was performed. Patients were selected for inclusion on the basis of the following criteria:

- A retrograde root canal retreatment technique was performed on teeth with apical pathosis
- Existing coronal restoration was adequate.
- No aggressive or moderate to severe chronic periodontal disease present.
- An American Society of Anesthesiologists (ASA) score of I or II.
- Radiographs documenting pre-treatment, post-treatment and follow-up were of good diagnostic quality.
- A documented 1-year recall (failure cases within 1 year were included).

Cases were excluded from the study if:

- A vertical root fracture was identified during surgery.
- A bone graft was used.
- Cases were a resurgery.

Surgical procedure

All clinical procedures were performed by a single operator (A.W.) utilizing a surgical operating microscope (SOM 62 Karl Kaps, Asslar, Germany). Cone beam computerized tomography (CBCT) scans were performed prior to surgery; scans were viewed in different planes (sagittal, coronal and axial) in the apical to coronal direction for better visualization and identification of the root canal system morphology.

Patients were anaesthetized with 2% lidocaine with 1 : 100 000 epinephrine (Septodont, Brampton, ON, Canada). A full-thickness flap was reflected 1 tooth mesial to 1 tooth distal of the surgery site. Osteotomy was performed with a size 3 round diamond bur in an Impact Air 45 handpiece (Palisades Dental LLC, Englewood, NJ, USA). An approximately 1-mm root-end resection was performed with a long shank fissure bur (254H Komet Dental, Lemgo, Germany). The root surface was inspected with micromirrors (Hu-Friedy, Los Angeles, CA, USA) under high magnification to identify the apical root canal system morphology and to verify the absence of any cracks and fractures. In cases where an isthmus was identified in the CBCT scan 2–3 mm from the apex and was not located after a 1-mm resection, an additional 1–2-mm resection was performed. In cases where an isthmus was not identified after a 3-mm resection, the main canals were prepared, and the isthmus was located on the inner canal wall and subsequently prepared with no further resection.

A retrograde canal preparation extending coronally as deep as possible was performed using pre-bent stainless steel size 30 and/or 35 ultrasonic files (Endosonore, Dentsply Sirona, Ballaigues, Switzerland),

mounted in a 120 ° ultrasonic file adapter (ST12A Enac, Tokyo, Japan) (Figs 1, 2 and 3).

The ultrasonic files were pre-bent to create preparation tips with various angles and lengths using a No. 139 round beak orthodontic plier according to the requirements of each individual case. The first file was usually pre-bent to a 3-mm tip length to enable access through a minimal osteotomy and to allow scouting and the initial cleaning and shaping of the root canal system. The ultrasonic unit was set to 25% power (No. 2.5 on a scale of 0-10 Enac, Tokyo, Japan), and the file was initially activated without water cooling to improve visibility and allow softening of the filling material. This step was followed by the activation of water cooling to wash out the root canal filling material and debris.

After the entire 3-mm tip entered the canal, it was replaced with increasingly longer tips to prepare the canal as far coronally as possible. During the procedure, the files were rebent to various angles according to the internal morphology to gain access to unprepared areas such as isthmi, fins and various canal ramifications.

A Stropko irrigator (Kerr Corporation, Orange, CA, USA) was used to dry the canals during the procedure to allow examination of the root canal system prior to placing the retrograde root canal filling. The retrograde preparations were sealed with IRM (Dentsply Sirona). The material was mixed to a thick consistency and rolled into small 2- to 3-mm cones that were delivered into the canal using W1-2 or W3-4 West perforation repair instruments (Kerr Corporation). The retro-filling material was compacted with an angled Rubenstein plugger (Jedmed Instruments Co., St Louis, MO, USA), and the outer surface was burnished with the round end of a Buchanan B-3 condenser (Kerr Corporation). After the initial setting, the retro-filling material was polished with a tungsten carbide polishing bur (H48 LUF, Komet Dental).

A postoperative radiograph was taken at this stage. The flap was repositioned and sutured with 5-0 or 6-0 PTFE sutures (Cytoplast, Osteogenics Biomedical, Lubbock, TX, USA). The sutures were removed after 7 days.

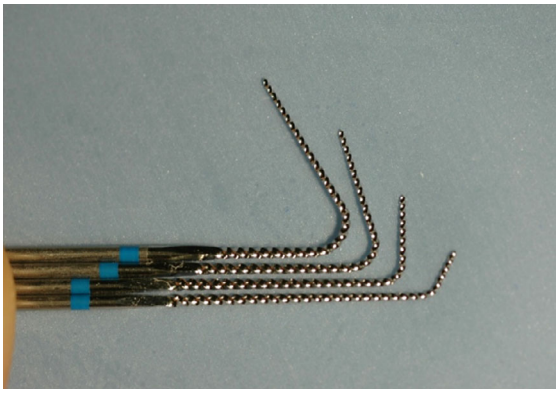

Figure 1 Ultrasonic files bent to various lengths and angles.

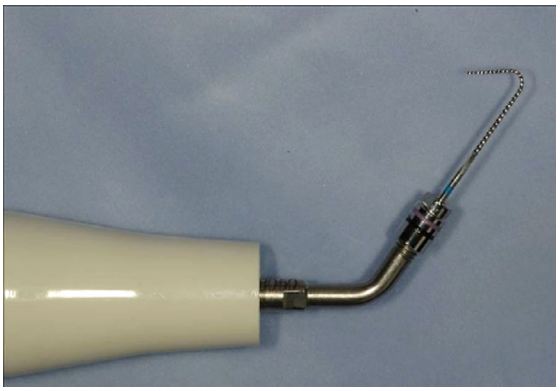

Figure 2 Pre-bent ultrasonic file mounted on an ultrasonic handpiece.

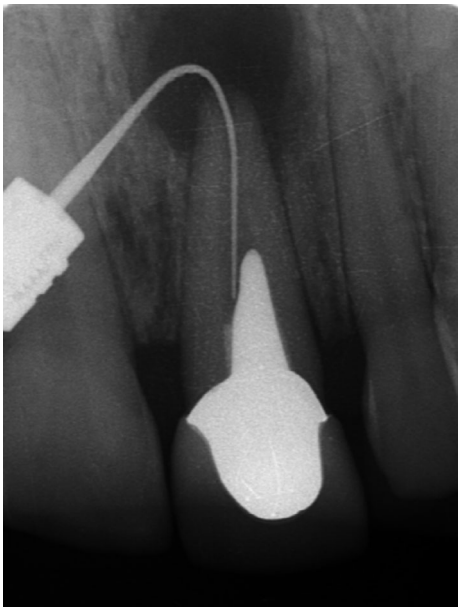

Figure 3 An example of a retrograde preparation extending coronally as deeply as possible: Tooth No. 21, pre-bent No. 35 ultrasonic file.

Clinical and radiographic evaluation

Follow-up with the patients was conducted after 1 year. The recall visit included a clinical examination and periapical radiographs obtained with a digital imaging system (Digora Optime Soredex, Helsinki, Finland) using a parallel technique (Rinn XCP system, Dentsply Sirona, York, PA, USA). Exposures of 0.12 s were obtained with a MinRay dental X-ray unit (Soredex) operating at 60–70 kV and 7 mA. The phosphor plates were immediately scanned after exposure using proprietary software (Dfw v.2.5, Soredex) with a 400-dpi scanning resolution. The clinical data from the recall record form included signs and symptoms, loss of function, tenderness to percussion and palpation, subjective discomfort, mobility, presence of sinus tract, periodontal pocket and the quality of coronal restoration.

The immediate postoperative radiographs and the follow-up radiographs were evaluated independently by two endodontic specialists (T.G. & R.W.). Intraobserver and interobserver calibration was performed with printed schematic illustrations of radiographic healing types and applied to 100 selected cases not participating in this study. In case of disagreement, the two evaluators discussed the case until an agreement on the outcome was reached.

The radiographic and clinical healing classification was based on the criteria established by Rud *et al.*(1972) and Molven *et al.* (1987); complete healing, incomplete healing, uncertain healing and unsatisfactory healing.

In cases of multirooted teeth, the outcome was determined according to the root with the poorest outcome.

Assessment of outcome

Patient-related factors, tooth-related factors and treatment-related factors were examined to identify prognostic factors that may affect the treatment outcome. Patient-related factors included age and gender. Tooth-related factors included tooth type, i.e. maxillary or mandibular incisors, canines, pre-molars and molars; the size of periapical radiolucency (measured on the preoperative CBCT), i.e. the diameter of small lesions was determined as ≤5 mm and of large lesions as >5 mm; and the presence or absence of an isthmus. The treatment-related factor was the length of the retrograde preparation ranging from 3 to 12 mm.

Statistical analysis

The association between both the age of the patients and the length of the retrograde preparation and the outcome was evaluated using the *t*-test. The association between patient gender, lesion size and the presence of an isthmus and the outcome was evaluated using Fisher's exact test. The association between tooth type and the outcome was evaluated using the Pearson chi-square test.

Cases with complete healing and incomplete healing were pooled and considered successful, and uncertain and unsatisfactory cases were considered failures. For statistical analysis of the prognostic factors, the dependent variable was the dichotomous outcome (i.e. success versus failure).

Multivariate analysis of the predisposing factors using logistic regression models was performed. Inter- and intraobserver analyses were performed using Kappa statistics.

All statistical analyses were performed with SPSS v 25.0 software (IBM Corp, Somers, NY, USA), and the level of significance was set at $P < 0.05$.

Results

Five hundred seventy-five patients with 721 treated teeth from January 2009 to December 2016 were included in the study. The demographic characteristics of the study subjects and the outcomes are summarized in Table 1. The overall success rate was 91.8% (88.9% complete healing and 2.9% incomplete healing), and the failure rate was 8.2% (2.7% uncertain healing and 5.5% unsatisfactory healing). The Kappa value for the intraobserver agreement was 0.94 for both observers and 0.93 for the interobserver agreement.

Age, gender, size of periapical radiolucency and isthmus presence had no significant influence on the outcome ($P > 0.05$). Tooth type had a significant influence on the outcome ($P = 0.008$). Mandibular incisors had a significantly lower success rate (71.4%) compared to other tooth types. The length of the retrograde root canal preparation also had an impact on the outcome. The average length of the retrograde preparation of the successful cases, 5.40 mm, was longer than that of the failing cases, 4.95 mm, which is a significant difference ($P = 0.034$). Multivariate analysis using logistic regression revealed that the only variable that had a significant association to the

Table 1 Treatment outcome by patient, preoperative and treatment factors

Factors	Success *N* (%)	Failure *N* (%)	Total *N*
Gender			
Male	227 (90.8)	23 (9.2)	250
Female	435 (92.4)	36 (7.6)	471
Age (mean)	48.37y	48.78y	721
Size of lesion			
5 mm≤	260 (92.2)	22 (7.8)	282
5 mm<	402 (91.6)	37 (8.4)	439
Tooth type			
Maxillary incisors	201 (93.1)	15 (6.9)	216
Maxillary canines	31 (96.6)	1 (3.1)	32
Maxillary pre-molar	140 (92.1)	12 (7.9)	152
Maxillary molar	140 (95.9)	6 (4.1)	146
Mandibular incisors	10 (71.4)	4 (28.6)	14
Mandibular canines	6 (100)	0 (0)	6
Mandibular pre-molar	32 (86.4)	5 (13.6)	37
Mandibular molars	102 (86.5)	16 (13.5)	118
Presence of an Isthmus			
Isthmus present	193 (91)	19 (9)	212
Isthmus absent	469 (92.1)	40 (7.9)	509
Length of retro-preparation			
3 mm	28 (87.5)	4 (12.5)	32
4 mm	177 (89.4)	21 (10.6)	198
5 mm	216 (91.9)	19 (8.1)	235
6 mm	115 (93.5)	8 (6.5)	123
7 mm	57 (93.4)	4 (6.6)	61
8 mm	35 (94.6)	2 (5.4)	37
9 mm	16 (94.1)	1 (5.9)	17
10 mm	12 (100)	0 (0)	12
11 mm	3 (100)	0 (0)	3
12 mm	3 (100)	0 (0)	3

outcome was the length of the retrograde preparation ($P = 0.016$, odds ratio = 1.299; C.I. 95% (1.050, 1.607), i.e. the longer the retrograde preparation, the better the outcome.

Discussion

The overall success rate of the 1-year follow-up of retrograde root canal retreatments was 91.8%. In the present study, 721 teeth were treated. Fifty-nine treated teeth failed, with no significant difference between teeth types except for mandibular incisors that had a significantly lower healing rate of only 71.4%. The fact that this subgroup consisted of only 14 teeth, of which 4 teeth failed, might make any in-depth analysis of this finding unwarranted. The results of this study corroborate previous findings of endodontic microsurgery meta-analyses that resulted in successful outcomes in approximately 90% of cases (Tsesis *et al.* 2009, 2013). However, there are several differences in the surgical technique performed in this study. Minimal root resection and maximal length retrograde preparation were performed to preserve the root length and to clean the canal space as coronally as possible (Figs 4, 5 and 6). Root-end resection alters the root-to-crown ratio and crown-to-root ratio. Data regarding the influence of root-end resection and changes of the crown-to-root ratio on the outcome of endodontic microsurgery are lacking (Von Arx *et al.* 2015).

The crown-to-root ratio is one of the primary variables in the evaluation of the suitability of a tooth as an abutment for a fixed or removable partial denture (Grossmann & Sadan 2005). In a study on periodontally treated teeth, an unsatisfactory crown-to-root ratio was among the clinical factors that resulted in poor initial prognoses (McGuire & Nunn 1996). In teeth with periodontal destruction and loss of marginal bone support, root-end resection may compromise periodontal support (Von Arx *et al.* 2015). Epidemiological studies show that periodontitis prevalence was positively associated with increasing age (Kassebaum *et al.* 2014, Eke *et al.* 2015). Therefore, one should take into account the possibility that a tooth that was surgically treated might develop, over time, periodontal disease or an existing disease could worsen.

Furthermore, teeth with long posts and/or short roots requiring surgery may necessitate alteration to the 3-mm root-end resection approach, and a minimal resection may preserve valuable canal length for proper retrograde preparation and sealing.

One of the goals of root-end resection is to create a surface for root-end inspection and management (Kim & Kratchman 2006, Von Arx *et al.* 2015). In some cases, a 1-mm resection may not be sufficient to identify an isthmus and/or additional canals. Studies have shown that the greatest incidence of isthmi has been found at 3–5 and 4–6 mm from the apex of the mesiobuccal roots of maxillary molars (Weller *et al.* 1995), and mesial roots of the mandibular first molars (Gu *et al.* 2009), respectively. In those cases, many of the isthmi might not be identified even after a 3-mm resection. In the present study, if an isthmus was apparent on the CBCT scan but was not located after 1-mm resection, an additional resection of 1–2 mm was performed. In cases where the isthmus was not identified on the resected root surface, the main canals were initially prepared, and the internal

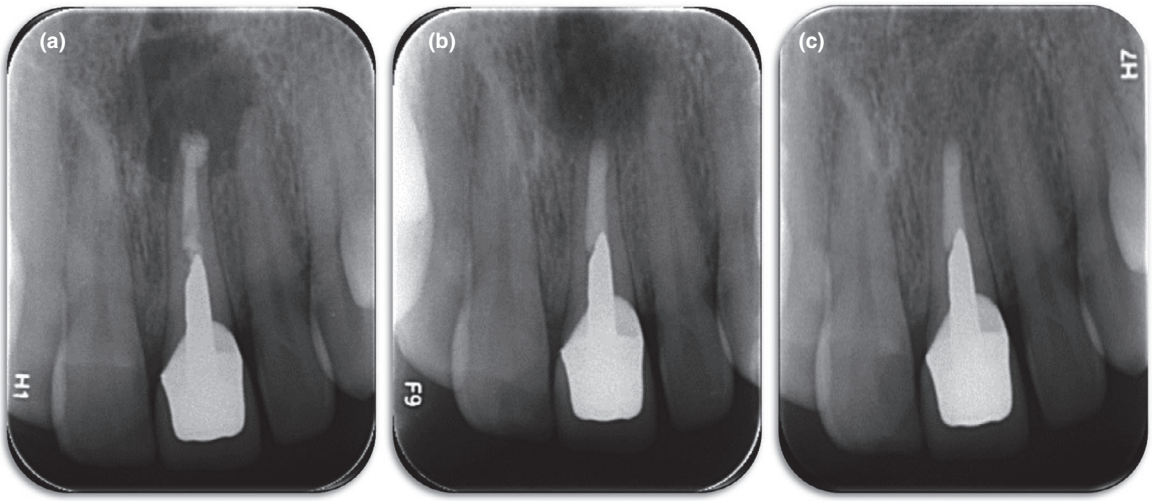

Figure 4 Tooth No. 21—Retrograde root canal retreatment. (a) Preoperative radiograph displays a large periapical lesion and extrusion of root canal filling material. (b) Postoperative radiograph demonstrating a minimal resection and a retrograde retreatment up to the post. (c) 1-year follow-up showing complete healing.

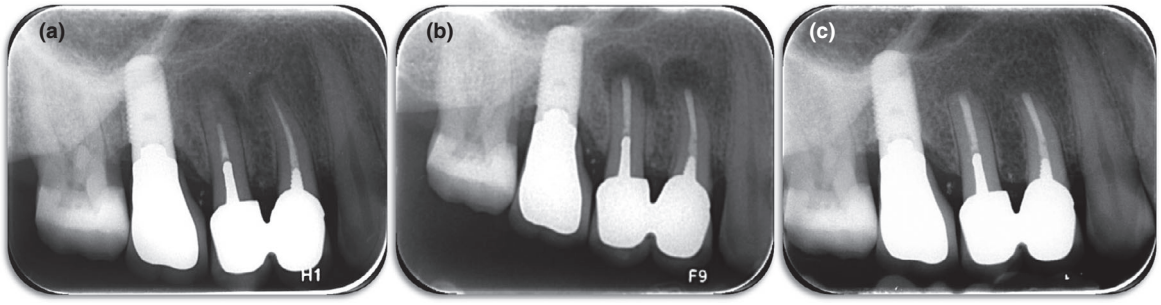

Figure 5 Teeth No. 14 and 15—Retrograde root canal retreatments. (a) Preoperative radiograph. (b) Postoperative radiograph demonstrating minimal resections and retrograde preparations and fillings to a depth of 7 and 8 mm in teeth No. 14 and 15, respectively. (c) One-year follow-up showing complete healing.

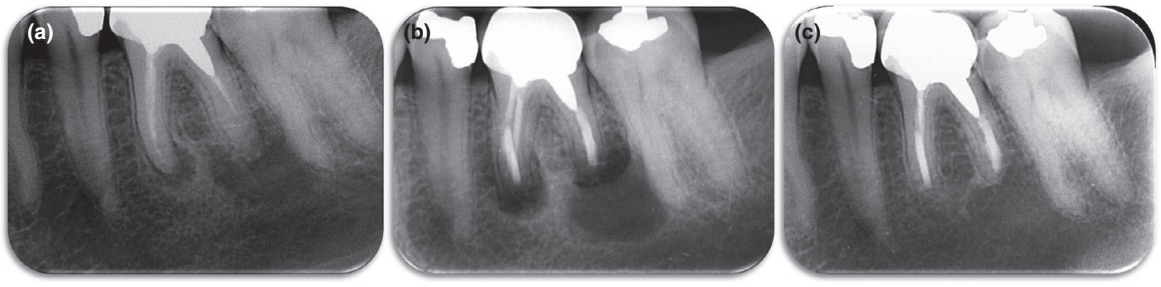

Figure 6 Tooth No. 36—Retrograde root canal retreatment. (a) Preoperative radiograph. (b) Postoperative radiograph demonstrating minimal resection and a retrograde preparation as coronal as practical. (c) 1-year follow-up showing complete healing.

walls towards the area of the suspected isthmus were inspected to identify and clean the isthmus from within the canals. The appropriate size of the ultrasonic file was pre-bent to address the isthmus in a precise and conservative manner without further root resection.

Cast surgical ultrasonic tips come in a variety of designs and coatings. In recent years, longer tips of 6 and 9 mm have become available on the market (Satelec Corp, Bordeaux, France). However, their sizes, angles and lengths are limited, and they are costly. Moreover, the insertion of the longer tips might be restricted in cases of small osteotomies or palatally inclined roots.

The main advantages of ultrasonic files are their versatility, flexibility and affordability. They can be bent in endless variety of angles and lengths to accommodate the specific characteristics of the root at hand. Different sizes and lengths of files can be used throughout the procedure. This versatility allows proper preparation of the main canal/s as coronally deep as practical and of irregular areas, such as the fins and isthmi. Furthermore, the flexibility of ultrasonic files allows the insertion of long ultrasonic files in cases of conservative osteotomies, while long cast tips may require enlargement of the osteotomy. However, ultrasonic files are fragile and might break in the canal during retro-preparation. To minimize the occurrence of this mishap, it is advisable to operate the file in minimal yet efficient power. In the case of file fracture, the fragment can be removed easily since it does not bind to canal walls.

Post-treatment apical periodontitis is almost always associated with intraradicular polymicrobial infection (Blome *et al.* 2008, Ricucci *et al.* 2009). The common technique of apical microsurgery addresses only the apical 6 mm of the root; i.e. a 3-mm root-end resection plus a 3-mm root-end preparation and filling (Kim & Kratchman 2006). Residual infection located coronally to the retrograde filling material might jeopardize the post-surgical resolution of the periapical lesion. The concept of retrograde endodontic retreatment aimed at debriding the root canal space as coronally as possible was originally suggested by Nygaard-Ostby (1971) and clinically explored by Reit & Hirsch (1986). They used Hedström files held at different angles with a haemostat to clean and shape the root canals and to produce a satisfactory seal. Amagasa *et al.* (1989) applied angled reamers and angled files held in broach holders for a similar purpose. Jonasson *et al.* (2008, 2017) explored Nygaard-Ostby's concept for initial retrograde endodontic treatment in cases with limited orthograde access. The outcome of a retrograde retreatment technique using ultrasonic files was first reported by Wang *et al.* (2004) as one of the surgical techniques used in the Toronto study. The procedure involved hand files adapted to the ultrasonic handpiece to clean the canal as far coronally as permitted by the restoration. The result was a 100% healing rate, but this technique was only applied to 7 teeth (Wang et al. 2004). In the present study, Nygaard-Ostby's concept was followed by utilizing ultrasonic energy through customized pre-bent ultrasonic files. The present study reveals that the length of the retrograde preparation was positively associated with the outcome; the longer the retrograde preparation, the better the outcome. It should be noted that the longer the retrograde preparation, the greater the potential for deviation from the original path of the canal. To avoid such faults, one should carefully examine canal curvature on the preoperative CBCT and frequently monitor the progression of the preparation in the coronal direction with the aid of a micromirror under high magnification.

In the present study, the immediate postoperative radiographs were compared to the 1-year follow-up radiographs according to the criteria for assessment of healing established by Rud et al. (1972). One may argue that using the immediate postoperative radiographs instead of the preoperative ones for comparison to the 1-year follow-up radiographs is misleading since the immediate postoperative radiographs contain a surgical 'crater' or radiolucency created by the surgical procedure itself. A decrease in the radiolucency size in the 1-year follow-up radiograph might be interpreted as a healing process of the lesion, when in fact it might merely be a healing process of the 'crater' formed during the surgery. In the criteria described by Rud et al. (1972), a decrease in the size of the rarefaction after 1 year is defined as 'uncertain healing' and the procedure is not considered a success. Furthermore, if this rarefaction is unchanged after 4 years it should be considered a failure. Andreasen & Rud (1972) found in histological examinations moderate to severe inflammation in these cases, explaining that if the noxious element is only reduced during the procedure, the rarefaction may decrease until a steady state exists between the noxious agent and the tissue response. In the present study, cases classified as 'uncertain healing' in the 1-year follow-up were considered a failure.

The scope of the present study is to describe an alternative surgical technique and to retrospectively investigate its outcome and potential predictors that may have an influence on the outcome. The present study lacks a control group; therefore, there is a need for a future prospective cohort study that would

compare endodontic microsurgery and retrograde root canal retreatment.

Conclusions

Retrograde root canal retreatment was successful in 91.8% of cases. This predictable success rate was achieved while minimizing the root-end resection and maximizing the preparation length. The length of the retrograde preparation was positively associated with the outcome; the longer the retrograde preparation, the better the outcome.

Conflict of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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