CE article
Treatment planning:
Retention of the natural dentition
and the replacement of missing teeth

technique
Twisted files and adaptive motion technology:
A winning combination

study
Long-term analysis of primary,
non-surgical root canal treatments
Still looking for MB2: Endodontic nirvana

Finding the Holy Grail. Grabbing the Brass Ring. Finding the MB2 canal in maxillary molars! Pie in the sky? We think not!

With all the technological advances that have occurred in dentistry, certainly in endodontics, the biologic objectives have remained the same, those being to eliminate and/or prevent apical periodontitis. How does one do this? There is no magic wand nor is there a simple recipe to achieve this objective. However, one thing is for sure, if a general practitioner embarks on root canal treatment, whether on a tooth with relatively simple or complex anatomy, he/she should be held to the a standard that is expected of a specialist for the procedure being performed; thorough debridement of the entirety of the canal anatomy, followed by three-dimensional obturation.

To achieve endodontic success one must be skilled, understand the biologic system that one is working in and understand the objectives of the treatment. One should also employ the correct armamentarium, as long as he/she first has the tools. High magnification and the development of ultrasonics for conventional endodontics have enabled many practitioners to treat complex root canal anatomic variations more thoroughly.

Dental imaging has made leaps and bounds with the advent and use of the cone beam computed tomography (CBCT). Limited field of view images taken preoperatively will allow a three-dimensional rendering of the tooth to be treated. In essence, this will provide the practitioner with a more precise ‘road map’ with respect to the anatomic makeup of the tooth to be treated. CBCT has enlightened us to the complexity of the root canal system and thereby obliges us to 3-D disinfection and obturation.

An updated joint position statement of the American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology is intended to provide scientifically based guidance to clinicians regarding the use of CBCT (available on AAE website).

In addition to the many recommendations that were given for the use of CBCT in endodontics, the position paper stated that ‘limited FOV [Field Of View] CBCT should be considered the imaging modality of choice for initial treatment of teeth with the potential for extra canals and suspected complex morphology, such as mandibular anterior teeth, and maxillary and mandibular premolars and molars, and dental anomalies’. Why look for an MB2 canal when it doesn’t exist and risk comprising the structural integrity of the tooth and risk perforation? After all, if it does exist then the CBCT may reveal it. That being said, one should also take the CBCT results with somewhat of a ‘pinch of salt’, as what often may appear as a lesion of endodontic origin may only be a variation of normal. A proper systematic diagnostic protocol should always be followed by, which includes but is not limited to, pulpal and periradicular testing of the tooth (teeth) in question.

So how do we reach this idyllic Endodontic Nirvana? Even with all the technological advances that we have at our fingertips, we need to provide the patient with best possible care, and the only way one can capitalise on these advances is plain old education, experience and practice, practice, practice!

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Treatment planning:
Retention of the natural dentition and the replacement of missing teeth

Author: Dr Scott L. Doyle, USA

Introduction

Preservation of the natural dentition is the primary goal of dentistry. Published surveys indicate that patients generally value teeth and express a desire to save their natural dentition in favour of extraction whenever possible. Significant technological and biological improvements have been made in all disciplines of dentistry, making long-term retention of natural teeth more attainable. Patients entrust dental professionals to make appropriate recommendations regarding the maintenance and restoration of their oral health and function. It is essential to employ an evidence-based, interdisciplinary approach that addresses the interests of the patient when determining the best possible course of treatment.

In July 2014, the American Association of Endodontists, in collaboration with the American College of Prosthodontists and the American Academy of Periodontology, hosted a two-day Joint Symposium titled Teeth for a Lifetime: Interdisciplinary Evidence for Clinical Success. Approximately 375 general dentists and specialists assembled in Chicago to focus on preserving the natural dentition. The educational program included evidence-based presentations on advanced regenerative techniques, improvements in technology, minimally invasive restorative methods and best practices for interdisciplinary treatment planning. Dr Alan Gluskin, chair of the 2014 Joint Symposium Planning Committee, concluded that the current evidence directs clinicians to consider saving the natural dentition as the first option when developing treatment plans.

Dental implants are one of the most significant advancements in contemporary dentistry. This innovation has had profound effects on endodontic, periodontic and prosthodontic treatment planning for the rehabilitation of edentulous spaces and for teeth with an unfavorable prognosis. Implant-supported restorations minimize unnecessary preparation of intact abutment teeth and allow fixed prosthodontic replacement when suitable abutments are absent. With appropriate usage and case selection, implant dentistry provides a viable option for the replacement of missing teeth.

There has been an increasing trend toward replacing diseased teeth with dental implants. Often, an inadequate or inappropriate indication for tooth extraction has resulted in the removal of teeth that may have been salvageable. Teeth compromised by pulpal or periodontal disease have value and should not be extracted without thoroughly evaluating restorability and potential retention therapies.
A recent systematic review published in the Journal of the American Dental Association highlights a key question: “Is the long-term survival rate of dental implants comparable to that of periodontally compromised natural teeth that are adequately treated and maintained?” Nineteen studies with a follow-up period of at least 15 years were included in the analysis. The results show that implant survival rates do not exceed those of compromised but adequately treated and maintained teeth. These findings support other studies comparing long-term survival of implants and natural teeth, providing an important message: Periodontally compromised teeth can be retained with quality treatment and appropriate maintenance. Therefore, it may be advisable to postpone implant consideration for the periodontitis-susceptible patient to fully utilize and extend the capacity of the natural dentition.

Treatment planning options

A key focus of the Joint Symposium involved treatment planning decisions regarding endodontic treatment and implant therapy. Should a tooth with pulpal disease be retained with root canal treatment and restoration, or be extracted and replaced with an implant-supported restoration? This assessment involves a challenging and complex decision-making process that must be customized to suit the patient’s needs and desires. The topic has received considerable attention in the literature, the media and at dental continuing education courses.

Endodontic treatment and implant therapy should not be viewed as competing alternatives, rather as complementary treatment options for the appropriate patient situation (Figs. 1a & b). Root canal treatment is indicated for restorably sound teeth with pulpal and/or apical pathosis. Endodontic treatment on teeth with nonrestorable crowns or teeth with severe periodontal conditions is contraindicated, and other options such as implant placement should be considered. When making treatment decisions, the clinician should consider factors including outcome assessment, local and systemic case-specific issues, costs, the patient’s desires and needs, aesthetics, potential adverse outcomes and ethical factors.

Outcome assessment: Success and survival

Treatment outcomes play a key role in the assessment of different treatment options. Patients often ask whether a procedure is going to be successful or not. This question can be challenging for a clinician to answer due to the variety of reported outcomes in the literature. There are differences in the methodology and criteria used to evaluate the outcomes for root canal treatment and implant prosthetics, which makes comparisons between success rates difficult, if not impossible. Endodontic studies have historically used “success” and “failure” as outcome measures and have focused on a strict combination of radiographic and clinical criteria. In contrast, the implant literature has primarily reported “survival,” i.e., the implant is either present or absent. Therefore, implant studies that solely evaluate survival as an outcome measure will likely publish higher success rates than endodontic studies that rely on biologic healing and factors related to the entire restored tooth. To establish more valid and less biased comparisons, the same outcome measures should be used. A more patient-centered measure is to compare the outcome of survival, which is considered to be an asymptomatic tooth/implant that is present and functioning in the patient’s mouth.

### Table 1: Survival rates following initial nonsurgical root canal treatment

<table>
<thead>
<tr>
<th>Author</th>
<th>Number of teeth</th>
<th>Follow-up (years)</th>
<th>Survival (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salehrabi and Rotstein</td>
<td>1,463,936</td>
<td>8</td>
<td>97</td>
</tr>
<tr>
<td>Chen et al.</td>
<td>1,557,547</td>
<td>5</td>
<td>93</td>
</tr>
<tr>
<td>Lazarski et al.</td>
<td>44,613</td>
<td>3.5</td>
<td>94.4</td>
</tr>
</tbody>
</table>

**Fig. 1a:** Pre-op image of tooth #19 with pulp necrosis and symptomatic apical periodontitis. The patient is interested in rehabilitation of the edentulous space. (Images courtesy of American Association of Endodontists)

**Fig. 1b:** Three-year recall image. The patient has benefited from both root canal treatment and implant therapy. (Courtesy of Dr Tyler Peterson and the University of Minnesota School of Dentistry)
Multiple large-scale studies including millions of teeth have used survival to assess the outcome following root canal treatment. An investigation using an insurance database of more than 1.4 million root canal-treated teeth demonstrated that 97 percent were retained within an eight-year follow-up period. Other studies show similarly high survival rates (Table 1). An epidemiological approach allows for the assessment of tooth retention from a large sample of patients experiencing actual care in private practices. Systematic reviews and controlled studies from academic settings complement the previous findings. Two prospective trials each reported 95 percent survival rates at four years and four to six years for teeth after initial root canal treatment.

Predictable tooth retention: Nonsurgical root canal treatment and restoration

The majority of endodontic treatment is performed by general dentists with a high degree of success. For complex cases, referral to an endodontist with additional training and expertise may result in more favourable outcomes and positive patient experiences. Interdisciplinary care is important for the management of endodontically treated teeth. The restorative dentist plays a significant role in the outcome by providing an appropriate and timely restoration. Root canal treatment is not complete until the tooth is coronally sealed and restored to function. Multiple studies have confirmed that a definitive restoration has a significant impact on survival. Therefore, the likelihood of a favorable outcome increases with both skillful endodontic care and prompt restorative treatment (Figs. 2a & b). Advancements in technology aid in attaining high levels of tooth retention. The dental operating microscope, nickel-titanium instruments, apex locators, enhanced irrigation protocols and dentin preservation strategies are examples of improvements that allow clinicians to predictably manage a greater range of treatment options. Additionally, cone beam-computed tomography facilitates more accurate diagnosis and improved decision-making for the management of endodontic problems.

Comparative studies: Endodontically treated teeth and single-tooth implants

Large-scale systematic reviews have addressed the relative survival rates of endodontically treated teeth and single-tooth implants. The Academy of Osseointegration conducted a meta-analysis using 13 studies (approximately 23,000 teeth) on restored endodontically treated teeth and 57 studies (approximately 12,000 implants) on single-tooth implants. The outcome data demonstrated no difference between the two groups during any of the observation periods. Another systematic review supported by the American Dental Association compared the outcomes of endodontically treated teeth with those of a single-
tooth implant-restored crown, fixed partial denture, and no treatment after extraction. At 97 percent, the long-term survival rate was essentially the same for implant and endodontic treatments. Both options were superior to extraction and replacement of the missing tooth with a fixed partial denture.

Retrospective studies also have compared the outcomes for the two treatment options. A study conducted at the University of Minnesota compared the outcomes of 196 restored endodontically treated teeth with 196 matched single-tooth implants. Both groups had 94 percent survival rates. The survival curves for these two groups are provided in Figure 3. Another investigation from the University of Alabama provided similar results.

Based upon similar survival rates, the decision to treat a compromised tooth endodontically or replace it with an implant must be based on factors other than treatment outcome. Several factors influence the decision-making process. The following lists provide an overview of case-specific factors that should be considered in making this treatment decision.

**Systemic factors**
- The list of potential risk factors for peri-implantitis or implant failure is extensive. It includes systemic disease, genetic traits, chronic drug or alcohol consumption, smoking, periodontal disease, radiation therapy, diabetes, osteoporosis, dental plaque and poor oral hygiene.
- There are few medical conditions that directly affect endodontic treatment outcomes. Risk factors that may be associated with decreased survival of root canal-treated teeth include smoking, diabetes, systemic steroid therapy and hypertension.
- Patients taking antiangiogenic or antiresorptive (i.e., bisphosphonates) medications may have an increased risk for developing medication-related osteonecrosis of the jaw. This may affect treatment planning for both implant and endodontic treatment.
- It is generally recommended to wait for the completion of dental and skeletal growth prior to implant placement.

**Local factors**
- Accurate diagnosis.
- Restorability assessment: removal of caries/restorations; adequate ferrule.
- Strategic nature of the tooth as it fits into the comprehensive restorative plan.
- Caries risk and oral hygiene.
- Periodontal assessment: tissue biotype, adequate biologic width.
- Presence of crack(s), root fracture(s), resorption.
- Occlusion and parafunction.
- Teeth with less than two proximal contacts and those serving as fixed partial denture abutments may have lower survival.
- Need for adjunctive treatment (crown lengthening, orthodontic extrusion, sinus lift, bone graft, etc.), which may impact financial cost and time to function.
- Quantity and quality of bone.
- Proximity to anatomical structures (maxillary sinus, inferior alveolar nerve, etc.).
- Implant esthetics in the anterior region may be challenging.

In addition to systemic and local factors, it is critical to include the patient’s concerns during treatment planning. Common patient-centered factors include costs, treatment duration, satisfaction with treatment and the potential for adverse outcomes.

Financial considerations can influence a patient’s decision when weighing treatment options. The availability of dental insurance may also impact choices. Endodontic treatment and restoration offer considerable economic advantages to the patient.
A benefit of root canal treatment is the short time frame required to completely restore both dental function and aesthetics. In one study of about 400 patients, the restored single-tooth implant showed a longer average and median time to function than similarly restored endodontically treated teeth. Additionally, the implant group had a higher incidence of post-treatment complications requiring subsequent treatment interventions. This increased post-operative care can impact patients in terms of additional visits, lost wages and unforeseen costs.

Clinicians should consider the patient’s preferences, which are often related to function, comfort and aesthetics. Tooth loss is associated with an impaired quality of life, and surveyed patients express a clear desire to save their natural dentition whenever possible. Large-scale surveys of post-endodontic patients have demonstrated that endodontic treatment not only preserves the natural tooth, but also significantly improves patients’ quality of life. More than 97 percent of patients report being satisfied with their endodontic treatment. If an implant is used to restore an edentulous space, a similarly high percentage of patients have a positive experience with implant therapy. Furthermore, comparative studies demonstrate that patients report a high degree of satisfaction with the overall experience following both procedures.

Despite high survival rates, both endodontically treated teeth and implants are susceptible to complications. Non-restorable caries, prosthetic failures, periodontal disease, crown/root fractures and specific endodontic factors are examples of complications following root canal treatment. Complications associated with implants and related prostheses include: surgical, implant loss, bone loss, peri-implant soft-tissue, mechanical and aesthetic/phonetic. A retrospective study directly compared the rates of additional interventions related to complications. Implant cases had a substantially higher need for subsequent intervention and maintenance visits than endodontically treated teeth. However, a more recent prospective study suggests that patients from both groups have minimal complications at one-year follow-up.

Endodontic retreatment options

The consequences of failure and subsequent treatment differ between endodontics and implants. Endodontic failure can usually be addressed successfully by retreatment, microsurgery, or by extraction and potential implant placement. Intervention after implant failure may vary from minimal restorative repairs to multiple corrective surgeries and/or the use of a different prosthesis.

Nonsurgical retreatment, or revision, is often the first choice to address post-treatment apical periodontitis, provided that the tooth is suitable for further restoration and that the restoration will have a good long-term prognosis. Current best evidence indicates that the survival of nonsurgical retreatment is similar to that of primary treatment, and that the two treatments share similar prognostic factors. Two studies specifically evaluated survival following retreatment. An epidemiological study using an insurance database of 4,744 retreated roots...
teeth reported an 89 percent survival rate at five years and a prospective trial of 858 retreated teeth reported a 95 percent survival at four years.

Modern techniques and rationale contribute to excellent potential outcomes for retreatment. An important factor when considering retreatment is the ability to identify and address the aetiology of post-treatment disease. Primary sources of non-healing are persistent intracanal microorganisms or ingress of microorganisms following treatment. If the aetiology of the problem is deemed correctable via an orthograde approach, retreatment is often the first choice. If not, a surgical approach may be the more predictable option.

Contemporary endodontic microsurgery has undergone significant technological and procedural advancements. Recently performed studies suggest that microsurgical techniques using biocompatible root-end filling materials provide significant improvements over traditional methods. A meta-analysis showed contemporary microsurgical techniques to have a significantly improved outcome (94 percent) compared to older techniques and instruments (59 percent). A recent systematic review investigating current microsurgery found survival rates of 94 percent at two to four years and 88 percent at four to six years, indicating that teeth treated with endodontic microsurgery tended to be lost at low rates over the time studied. Microsurgery, with appropriate case selection, is a predictable procedure for teeth that may have been considered for extraction in the past.

Ethics and interdisciplinary consultation

Clinicians are ethically bound to inform patients of all reasonable treatment options, explain the risks and benefits involved with the available treatment options, and obtain informed consent before initiating treatment. This information should be conveyed in an impartial manner. Patients value participation in the decision-making process and should be encouraged to exercise autonomy by communicating their preferences. Clinical treatment decisions regarding either endodontic treatment or tooth extraction with implant therapy must always be made in the best interest of the patient using the best, most current evidence.

Should it be necessary, experts from the dental team may need to be called upon to assist the clinician in rendering the highest quality of care (Figs. 5a & b). The standard of care must be applied equally to all clinicians, generalists and specialists alike. The AAE’s Endodontic Case Difficulty Assessment Form and Guidelines provides valuable information to aid the clinician in case selection and determining whether to treat or refer. Patients are deserving of the best possible outcome for each case. Interdisciplinary communication and collaboration during treatment planning maximizes this likelihood.

Specialists and restorative dentists should be viewed as partners in the treatment planning team. Endodontists are uniquely positioned to evaluate the restorability and prognostic longevity of teeth and recommend whether to attempt natural tooth preservation or consider extraction and replacement with an implant. Likewise, the endodontist should be well-versed in implant treatment planning to assist patients and referring colleagues in making an informed choice regarding all replacement options.

If a tooth has a questionable prognosis, the endodontic specialist becomes an indispensable part of the treatment planning team. The endodontist has experience with various treatment options that have potential to preserve the natural dentition. Consultation regarding a questionable tooth is often in the patient’s best interest prior to considering extraction. If the prognosis of a restorable tooth is categorized as questionable or unfavourable in multiple areas of evaluation, extraction should be considered after appropriate consultation with all relevant specialists. Only then is the decision to extract an informed choice. Extraction is an irreversible treatment, but if necessary, dental implants provide an excellent option to replace missing teeth (Figs. 6a & b).
Case report

This case report demonstrates an alternative treatment option for a patient to save their natural tooth. A 70-year-old female presented to an endodontist’s office with a complaint of persistent pain to biting. Tooth #31 had a history of root canal treatment and coronal restoration. A thorough examination, including CBCT, led to the diagnosis of previously treated tooth #31 with symptomatic apical periodontitis.

A detailed explanation of the risks and benefits associated with all treatment options was presented. The patient expressed a strong desire to save her tooth and consented to intentional replantation. Tooth #31 wasatraumatically extracted and continuously hydrated with Hanks’ Balanced Salt Solution. No cracks or fractures were visible. Apical microsurgery was performed extraorally. The root end was resected, ultrasonically prepared and filled with mineral trioxide aggregate. The tooth was replanted. The patient remains asymptomatic and very satisfied with her treatment.

A recent systematic review and meta-analysis revealed a mean survival rate of 88 percent for intentional replantation.* With careful case selection, intentional replantation may allow for a reasonable, cost-effective treatment option for teeth that do not heal following endodontic treatment. Clinicians are advised to explore all options before recommending extraction. Referral to an endodontist can aid in the retention of a compromised tooth.

Conclusion

Patients are living longer; therefore, preservation of the natural dentition is more important than ever. Helping patients maintain their "Teeth for a Lifetime" is the fundamental goal of dentistry and often aligns with the desires of the patient. A wide range of endodontic procedures result in a high level of tooth retention and patient satisfaction. Large-scale studies provide strong support that the restored endodontically treated tooth offers a highly predictable, long term approach to preserving "nature’s implant"—a tooth with an intact periodontal ligament.

Thus, excellent endodontic treatment followed by an immediate restoration of equal quality promises to give patients service and function while maintaining their esthetics for years. The results of multiple studies indicate that the high survival rates for the natural tooth are similar to those reported for the restored single-tooth implant.

Therefore, clinicians must consider additional factors when making treatment planning decisions, all of which must be in the best interest of the patient. Endodontic treatment and implant therapy should not be viewed as competing alternatives, rather as complementary treatment options for the appropriate patient situation._

Editorial Note: This article originally appeared in ENDODONTICS: Colleagues for Excellence, Spring 2015. Reprinted with permission from the American Association of Endodontists, ©2015. The AAE clinical newsletter together with a complete list of references are available at www.aae.org/colleagues.

Case report contributed by Dr Robert S. Roda.


about

Dr Scott Doyle was raised in Eau Claire, Wis. He received his BS from the University of Wisconsin-Madison in 1995 and his DDS from the University of Minnesota in 1999. After graduation from dental school, Doyle served in the United States Air Force for seven years. His first assignment was at Eglin Air Force Base, Florida, where he completed an advanced education in general dentistry residency. He practiced as a general dentist for two years at Altus Air Force Base, Oklahoma, prior to his acceptance into an endodontic residency. Doyle obtained both his MS and certificate in endodontics from the University of Minnesota in 2004. He is a diplomate of the American Board of Endodontics, attaining board certification in 2011. He currently serves as an associate clinical professor for the Division of Endodontics at the University of Minnesota. He is a member of the American Dental Association, the Minnesota Dental Association, the Minnesota Association of Endodontists and the American Association of Endodontists, as well as a variety of study clubs. He is currently president of the Minnesota Association of Endodontists.
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Twisted files and adaptive motion technology:
A winning combination for safe and predictable root canal shaping

Authors: Dr Gary Glassman, Canada; Prof. Gianluca Gambarini, Italy & Dr Sergio Rosler, Argentine

The ultimate goal of endodontic treatment is the prevention and/or treatment of apical periodontitis, such that there is complete healing and absence of infection while the overall long-term goal is the placement of a definitive, clinically successful restoration and preservation of the tooth.

Successful endodontic treatment depends on a number of factors, including proper instrumentation, successful irrigation and decontamination of the root-canal system right to the apical terminus in addition to hard to reach areas such as isthmuses, and lateral and accessory canals (Fig. 1a & 1b).

The challenge for successful endodontic treatment has always been the removal of vital and necrotic remnants of pulp tissue, debris generated during instrumentation, the smear layer, micro-organisms, and micro-toxins from the root-canal system.

It has been accepted that even with the use of rotary instrumentation, the nickel-titanium instruments currently available only act on the central body of the root canal, resulting in a reliance on irrigation to clean beyond what may be achieved by these instruments.

"Shaping canals creates sufficient space to hold an effective reservoir of irrigant that, upon activation, can penetrate, circulate and digest tissue from the uninstrumentable portions of the root-canal system."

Several challenges often arise during root canal preparation. Some of the most common ones are an-
atomic factors that may prevent negotiation to the apical termini, as well as ledge formation, perforation and file separation.

The introduction of Nickel-Titanium (NiTi) alloy in endodontics presented a significant improvement, allowing good results in terms of cleaning and shaping of root canals, while reducing operative time and minimising iatrogenic errors.9, 10

Thanks to the superior mechanical properties of the NiTi alloy, it was possible to use endodontic instruments of greater tapers in continuous rotation, increasing the effectiveness and rapidity of the cutting. However, several studies reported a significant risk of intracanal separation of NiTi rotary instruments.11–14 In fact, file separation via torsional and cyclic fatigue has created the biggest fear and risk for dentists using rotary NiTi files for root canal treatment.11, 12, 15

Although multiple factors contribute to file separation, cyclic fatigue has been shown as one of the leading causes.15 Fatigue failure usually occurs by the formation of microcracks at the surface of the file that starts from surface irregularities often caused by the grinding process during the manufacturing.

During each loading cycle microcracks develop, propagating getting deeper in the material, until complete separation of the file occurs.17 All endodontic files show some irregularities on the surface, and inner defect, as a consequence of the manufacturing process, and distribution of these defects influence fracture strength of the endodontic instruments.18, 19

Since the introduction of NiTi in 198820, varied instrument designs with claims of superior cyclic fatigue resistance have been propagated. However, there were no major changes in the manufacturing process/raw materials until the introduction of the second generation of NiTi files, ie, M-Wire (DENTSPLY Tulsa Dental Specialties) in 2007 and Twisted File (TF, Kerr Endodontics Formerly Axis/SybronEndo) in 2008.

TF instruments are manufactured using a proprietary heat treatment technology that changes the crystalline structure completely so the triangular cross section NiTi file blank can be twisted while maintaining the natural grain structure. More precisely, TF instruments are created by taking a raw NiTi wire in the austenite crystalline structure phase and transforming it into a different phase of crystalline structure (R-phase) by a process of heating and cooling. In the R-phase, NiTi cannot be ground but it can be twisted. Once twisted, the file is heated and cooled again to maintain its new shape and convert it back into the austenite crystalline structure, which is super elastic once stressed. The manufacturing process aims at respecting the grain structure for maximum strength as grinding creates microfracture points during the manufacturing of the instruments. Because TF files are twisted and not ground, no surface microfractures occur on their surface and therefore do not need be polished away; thereby not dulling the cutting edges and retaining their efficient cutting ability.21–23

Because of the increased flexibility, the TFs maintains the original canal shape better, minimises canal transportation and stays centred even in severely curved root canals.24, 25

In addition to the development of heat treated TF technology to improve the performance and safety of NiTi instruments, the file design has also been changed with respect file dimensions, tip configuration, cross-section and flute design. More recently, a third factor has become important in this search for stronger and better instruments: Movement Kinematics, the branch of motion in which the objects move.26

For more than a decade, NiTi instruments have been traditionally used with a continuous canal shaping technique.15

Fig. 2: Colour-Coded File Identification. An intuitive, colour-coded system designed for efficiency and ease of use. Just like a traffic light — start with green and stop with red.

Fig. 3: Elements™ Motor. Settings for TF™ Adaptive, TF™, K3, Lightspeed, M4 Safety Handpiece and custom settings for personal preference.
rotary motion, but more recently a new approach to
the use of NiTi instruments in a reciprocating move-
ment had been introduced by Yared. The clockwise
(CW) and the counterclockwise (CCW) rotations used
by Yared were four-tenths and two-tenths of a circle
respectively and the rotational speed utilised was 400
rpm. The concept of using a single NiTi instrument
to prepare the entire root canal was made possible
due to the fact that a reciprocating motion is thought
to reduce instrumentation stress.

Recent literature data shows that a reciprocating
motion can extend cyclic fatigue resistance of NiTi
instruments when compared to continuous rota-
tion, mainly because it reduces instrument stress.
As the instrument rotates in one direction (usually the
larger angle) it cuts and becomes engaged into the
canal then it disengages in the opposite direction
(usually with the smaller angle) and the stresses are
therefore reduced. Following these concepts new
instruments have been recently commercialised; Reciproc (VDW) and WaveOne (DENTSPLY Maillefer),
which uses specifically developed motors that pro-
duce a specific reciprocating movement (using ap-
proximately 150 to 30° angles).

This reduction of instrumentation stress (both tor-
sional and bending stress) is the main advantage of
reciprocating movements. It has been shown that a
lot of different reciprocating movements can be used,
each one affecting the performance and the safety
of the NiTi instruments. Therefore, when discussing
the advantages and disadvantages of reciprocation,
the exact motion should also be mentioned, since
the actual angle of reciprocation can have substantial
influence on both the clinical and experimental be-

Another possible advantage of reciprocation could
be better maintenance of original canal trajectory,
mainly related to lower instrumentation stress and
consequently its elastic return. However, it must be
underlined that reciprocation does not affect the in-
herent rigidity of the instruments. If a quite rigid Niti
instrument of greater taper is slightly forced into a
curved canal, it will create more canal transportation
than a more flexible one, due to its inherent tendency
to straighten. Moreover, tip design could strongly in-
fluence canal transportation, with a cutting tip being
more dangerous that a non-cutting pilot tip.

While reciprocation with NiTi instruments have be-
come very popular in recent years, with a significant
number of published articles, some of these studies
have shown that there is also inherent disadvantages
in the reciprocating movements.

It is well known that a small inadvertent extrusion
of debris and irrigants into the periapical tissues is
a frequent complication during the cleaning and
shaping procedures, both with manual stainless
steel and nickel-titanium rotary instrumentation

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**Fig. 4:** The motion of TF™ Adaptive instrument changes from rotary into reciprocation mode, with specifically designed CW and CCW angles which may vary from 600–0° to 370–50°.

**Fig. 5:** File size reference chart.
techniques. However, recent studies have shown that commercially available reciprocating instrumentation techniques seem to significantly increase the amount of debris extruded beyond the apex and, consequently, the risk of postoperative pain. A clinical study comparing Reciproc and NiTi rotary instruments has also confirmed these findings.

Since reciprocation movement is formed by a wider cutting angle and a smaller releasing angle, while rotating in the releasing angle, the flutes will not remove debris but push them apically. Reciproc and WaveOne motions are very similar (even if not precisely disclosed by manufacturers), and this fact could also explain the higher incidence and intensity of postoperative pain that has been found in recent research studies.

Moreover, both WaveOne and Reciproc techniques use a quite rigid, large single-file of increased taper (usually 08 taper, size 25), which is directed to reach the apex. In many cases, in order to reach the apical working length, reciprocating instruments are used with apically directed pressure, which produces an effective piston to propel debris through a patent apical foramen, and possibly directing debris laterally, making canal debridement more difficult. Since instruments are commonly used without first performing preliminary coronal enlargement, this may result in a greater engagement of the file flutes and consequently may produce more torque and/or applied pressure on the file. Moreover, the cutting ability of a reciprocating file is decreased when compared to continuous rotation. Debris removal is also less, thus increasing the frictional stress and torque demand on the file, due to entrapment of debris within the flutes. To reduce this tendency some authors have advocated the use of NiTi rotary glide path instruments, before using a WaveOne or Reciproc instruments, but in this case the overall technique is no longer a single file technique but a more complex and more costly technique which utilises two different types of NiTi instruments, glide path instruments and then shapers.

TF Adaptive

The TF Adaptive technique has been proposed in order to maximise the advantages of reciprocation, while minimising its disadvantages. By using a unique, patented motion, the innovative TF Adaptive Motion technology, together with an original three-file technique, most clinical cases can be treated effectively and safely (Fig. 2).

TF Adaptive employs a patented unique motion technology, which automatically adapts to instrumentation stress, when used in the Elements Motor while in TF Adaptive setting (Fig. 3). When the TF Adaptive instrument is not (or very lightly) stressed in the canal, the movement can be described as a continuous rotation, allowing better cutting efficiency and removal of debris. The cross-sectional and flute design are meant to perform at their best in a clockwise motion.

More precisely, it is an interrupted motion with the following CW-CCW angles: 600–0°. This interrupted motion is as effective as continuous rotation in lateral cutting, allowing optimal brushing or circumferential filing for better debris removal in oval canals. This interrupted motion also minimises iatrogenic errors by reducing the tendency of ‘screwing in’ (aka pull down), that is commonly seen with NiTi instruments of great taper that are used in continuous rotation.

On the contrary, while negotiating the canal, due to increased instrumentation stress and metal fatigue, the motion of the TF Adaptive instrument changes into a reciprocation mode, with specifically designed CW and CCW angles that may vary from 600–0° to 370–50° (Fig. 4). These angles are not constant, but vary depending on the anatomical complexities and the intracanal stresses placed on the instrument. This ‘adaptive’ motion is therefore meant to reduce the risk of intracanal failure, without affecting performance, due to the fact that the best movement for each different clinical situation is automatically selected by the Adaptive motor. It is quite interesting that the clinician will hardly perceive the differences in the changing motion, due to a very sophisticated algorithm, which permits a smooth transition between the changing angles.

As far as disadvantages of reciprocation are concerned, TF Adaptive motion is a reciprocating motion...
The TF Adaptive technique is basically a three-file technique, designed to treat the majority of cases encountered in clinical practice. Available are two sets of three-file systems, one for small, calcifying and severely curved canals and one system for more 'standard' and larger canals, allowing adequate taper and increased apical preparation in both scenarios. The number of instruments within each sequence can also vary and adapt to canal anatomy, with the last instrument of the sequence used only for smaller or more curved canals.

As mentioned before, flexibility is a fundamental property to minimise iatrogenic errors while negotiating canals, both in reciprocation and in continuous rotation. The use of a reciprocating movement, therefore, does not significantly help a NiTi instrument of greater taper to negotiate curved canals with no iatrogenic errors. It mainly helps to reduce instrumentation stress and the risk of intracanal failure. In addition, a study aimed to compare the frequency of dentinal microcracks after root canal shaping with two reciprocating (Reciproc and WaveOne) and one combined continuous reciprocating motion (Twisted Files Adaptive (TFA)).

Ninety molars were chosen and divided into three groups of 30 each. Root canal preparation was achieved by using Reciproc R25, Primary WaveOne and TFA systems. All the roots were horizontally sectioned at 15, 9 and 3 mm from the apex. The slices were then viewed each under a microscope at x25 magnification to determine the presence of cracks. The absence/presence of cracks was recorded, and the data were analysed with a Chi-square test. The significance level was set at P < 0.05. The results found that instrumentation with Reciproc produced significantly more complete cracks than WaveOne and TFA (P = 0.032). The TFA system produced significantly less cracks than the Reciproc and WaveOne systems apically (P = 0.004). The study concluded that within the limits of this study, the TFA system caused less cracks then the full reciprocating system (Reciproc and WaveOne). Single-file reciprocating files produced significantly more incomplete dentinal cracks than full-sequence adaptive rotary motion.39
when a greater apical enlargement is needed due to larger original canal dimensions and/or enhanced final irrigation techniques. The sequences are also different in their shaping concepts. Each file of the sequence being used is taken to full working length in a ‘crown down’ manner so that the root canal wall is internally sculpted incrementally, allowing dentin debris and tissue to be evacuated coronally rather than to be pushed apically. This may reduce the risk of canal blockage and the extrusion of debris into the apical tissues. The SM 1 file (single colour band green, 04 taper 20 tip size) is an excellent flexible Glide Path file which may be used with either sequence to pre-enlarge the canal thereby decreasing instrument stress for the next larger size file in sequence. This also allows better maintenance of the original canal trajectory (Figs. 2 & 5).

The final apical enlargement with a size #35 file is not only meant to allow the use of the Endovac (EndoVac Kerr Endodontics, Orange, CA) irrigation technique, but to improve canal shaping by touching more canal walls. Figure 6 clearly shows how improved and deeper the apical one-third shape is when a 08 taper 35 tip instrument follows a 08 taper 25 tip instrument. This is why in the majority of cases two instruments are much better than a single file technique, provided that the second instrument is a flexible one. The superior flexibility allowed by the use of TF technology permits TF Adaptive to follow these criteria, and safely enlarge canals with minimal risk of iatrogenic errors like tooth weakening and canal/apical transportation. The use of a more rigid alloy would have not made this possible, especially in curved canals.¹⁵

TF Adaptive technique

TF Adaptive is an intuitive, color-coded system designed for efficiency and ease of use. The colour-coded system is based on a traffic light. The first instrument in sequence is green. The second instrument in sequence is yellow and the third instrument in sequence, if required, is red. Green means go. Yellow means continue or stop. Red means stop (Fig. 2).

Coronal access and glide path

1. Place rubber dam.
2. Obtain straight line coronal access with slightly diverging axial walls adhering to the concept of Minimally Invasive Endodontics.³⁷
3. Achieve apical patency and establish an apical glide path using #8 hand file, follow that with a #10 hand file and continue at least with a #15 hand file. Glide path may be facilitated with the M4 Safety Handpiece (Kerr Endodontics, Orange, CA) (Fig. 7). The pulp chamber should be filled brimful with NaOCl (Sodium Hypochlorite).

Canal size and file sequence determination (Figs. 5 & 8)

Small Canals (SM)
Using tactile feel, if you struggle to get a #15 K-File to working length (WL) then the canal size is deemed to be ‘small’. Use the Small Pack (one colour band) and its instrument sequence. The small sequence may also be used in severely curved canals as well as roots that may be very thin and the risk of strip perforation is a possibility.

Medium/Large Canals (ML)
Using tactile feel, if a #15 K-File feels loose at working length then the canal size is deemed to be ‘medium/large’. Use the Medium/Large Pack (two colour bands) and its instrument sequence.

Establish working length
Working length should be established with a reliable apex locator. A radiograph may help the clinician as well.

TF Adaptive canal shaping technique

1. Use the ‘TF Adaptive’ setting on your Elements Motor. Figure #3
2. Ensure the pulp chamber is flooded with NaOCl or EDTA and make sure the file is rotating as you enter the canal.
3. Slowly advance the green (SM1 or ML1) with a single controlled motion until the file engages dentin then completely withdraw the file from the canal. Do not force apically. Do not peck.
4. Wipe off the flutes. Deliver irrigant to the pulp chamber and confirm canal patency with a #15 handfile K-File.
5. Repeat steps 3 and 4 using the file you started with until working length is achieved.
6. Repeat steps 3 and 4 with the yellow SM2 or ML2 until the file reaches working length. If the desired apical size is achieved the sequence is complete. For larger apical sizes, repeat steps 3 and 4 with the red SM3 or ML3 until the file reaches working length.

Note: All TFA files may be used in a brushing manner directed towards the external surface of the root away from the canal curvature when retrieving the file from the canals.

Irrigate and dry

When irrigating with EndoVac (apical negative pressure irrigation system), in small canals, you must take SM3 to working length. In medium/large canals, you must take at least ML2 to working length. Note that the Microcannula is .32 mm in diameter (Fig. 9). TF Adaptive matching Paper Points may be used to dry the canals.

Obturation

TF Adaptive matching Gutta Percha in combination with the Elements Free Cordless Obturation system may be used to obturate the root canal system. Alternatively, TF Adaptive carriers may be used.

Conclusions

TFA employs Twisted File technology and Adaptive Motion Technology. The TF Adaptive file design is based on clinically proven Twisted File technology, which means the file is twisted to shape for improved file durability, features R-Phase Technology to improve file flexibility and strength while maintaining the original canal curvature minimizing canal and apical transportation (Fig. 10).

Adaptive Motion Technology is based on a patented, smart algorithm designed to work with the TF Adaptive file system. The authors have also found that Adaptive Motion Technology works well with other ground file rotary systems making their use safer especially in smaller and curved canals. This technology allows the TF Adaptive file to adjust to intra-canal torsional forces depending on the amount of pressure placed on the file. This means the file is in either a rotary or reciprocation motion depending on the situation and adjusts appropriately.

This winning combination results in exceptional debris removal with the tried and trusted classic rotary Twisted File design and less chance of file pull down and debris extrusion with Adaptive Motion Technology.

Editorial Note: A complete list of references is available from the publisher.

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Disclaimer:

Drs. Gambarini and Glassman are the inventors of Adaptive Motion and receive a nominal royalty from Kerr.

authors

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HyFlex™ EDM

- Up to 700% higher fracture resistance
- Specially hardened surface
- Less filing required for treatment success

ORIFICE OPENER (optional) 25/.12

Glidepath File 10/.05

HyFlex™ OneFile 25/ ~

FINISHING FILES (optional) 40/.04 50/.03 60/.02

Coltene
From a distal

Author: Dr Sam Alborz, USA

Introduction

Limited workspace is a common problem in endodontic treatments. Before the arrival of pre-bendable NiTi files, a lot of RCT’s seemed to be almost inexecutable due to severe constraints in the access area. The following three cases illustrate how modern endodontic instruments help specialists to enter a new era of canal preparation, particularly if the apex is comparatively hard to reach.

Standard endodontic treatment begins with placement of a dental dam to isolate the working environment, access to the canal via opening of the pulp chamber, and gauging the correct working length using a state-of-the-art electronic apex locator. However, root canals often come in extraordinary shapes: an unusually curvy anatomy with hidden accessory canals or horizontal branches might pose a real challenge to the most experienced of endodontic experts. If the tooth is in a remote position or craniomandibular problems are added to the picture, the task is even more difficult. Thankfully modern endodontics offers practitioners a whole range of clever instruments and dental materials that ensure an effective and reliable preparation and filling of the canal system. This is good news to endo-specialists given that not all cases allow standard procedures – or following the words of the old Bette Midler song: sometimes the world looks different ‘from a distal’.

Case presentation

Necrosis in S-shaped canals

In our first case, a 23-year-old male patient was referred to our dental practice with chief complaint of pain in the lower left mandible. The radiograph showed deep caries approaching the pulp chamber and clinical testing revealed a diagnosis of irreversible pulpitis with symptomatic apical periodontitis (Fig. 1). Further review of the radiographs showed that tooth 18 had a very complex anatomy of the mesial roots: the canal system was almost S-shaped and the apex therefore would be difficult to reach. In addition to the distinct mesial-distal curvature there was a significant faciolingual curvature associated with the mesial roots which was discovered during hand instrumentations. Yet, the difficult anatomy of the root canal system itself was not the only constraining factor that considerably narrowed work space. To make things even more challenging, the patient had a severe class II skeletal relationship. Together with the posterior position of the offending tooth, this combination limited access to the canal openings even further.

The insufficient interocclusal space did not allow a common NiTi 21 mm rotary instrument to fit into the canal. For this reason, a special NiTi file system by Swiss dental specialist COLTENE was used for canal preparation. The HyFlex EDM is a modular designed nickel titanium file system: in close cooperation with
leading universities and international endo-specialists, the renowned research department of the company developed an extremely versatile concept which meets various demands. The abbreviation ‘EDM’ stands for a specific manufacturing process named ‘Electrical Discharge Machining’, which produces a unique surface (Fig. 2). The spark erosion employed improves cutting performance, as the created structure can be compared with the serrated edge of a knife you use for cutting bread at home. Due to its special material properties, the file is virtually unbreakable and predestined for dentists who require fast and reliable results using a reduced file sequence.

In the case described we benefitted first and foremost from the so-called ‘Controlled Memory’-effect (CM): similar to classical stainless steel files, HyFlex files can be pre-bent and considerably help in preparation of distal molars (Fig. 3, 4). At the same time they do not bounce back like classic NiTi files, which means that they move in an optimal way in the centre of the canal. During autoclaving, reusable CM-treated files return to their initial shape because they are not plastically deformed. Due to the special situation of the patient the pre-bent EDM files were the only files that would fit in the limited working space. Interestingly, the 25 mm EDM file fit in a space that would not allow a 21 mm traditional rotary NiTi.

To create a suitable glide path, both mesiobuccal and mesiolingual canals were handfiled to a size 15 file. All pulpal tissue was removed after opening the pulp chamber and canal clearance was checked thoroughly. For the actual preparation, the use of a universal EDM file in ISO size 25 totally sufficed (Fig. 5). With the flexible file we were able to instrument the mesial canals to a working length of 22 mm. Keeping its pre-bent shape, the instrument permitted to work without any stress and when the apex was gauged in the distal canal, a size 30 hand file seemed to fit in quite comfortably. Consequently, a 40/0.04 HyFlex EDM finishing file was used to enlarge the apical aspect of the two distal canals. It is important to point out that thorough irrigation was performed with sodium hypochlorite between every file. At the end of the procedure the canals were irrigated with NaOCl, EDTA and CHX under acoustic streaming. The canals were then dried via microsuction followed by the insertion of the corresponding paper points. In the end, the canals were obturated with the help of the traditional warm vertical compaction technique (Fig. 6). The pulpal floor was sealed with a layer of glass ionomer, sponge pellet (to act as a spacer) and a dual-cured temporary filling material consisting of zinc oxide and zinc sulphate over the top. A post-op radiograph was obtained (Fig. 7) and after the successful endodontic treatment the patient was subsequently referred to his general dentist for the definitive restoration of the tooth.

Fig. 3: Pre-bendable EDM File 60/.02.
Fig. 4: Pre-bent EDM File 60/.02.
Fig. 5: HyFlex EDM One File.
Fig. 6: Post-op (clinical) situation.
Fig. 7: Post-op situation.
Abrupt canal curvature
Our second case proved to be equally challenging: a 24-year-old female patient entered our referral practice with a necrotic pulp in tooth 18. The opening was limited and once again, the tooth was positioned very distal with only limited space for instrumentation. The root canals were highly curved with sudden sharp dilacerations (Fig. 8). After consultation, the patient agreed to root canal treatment.

The dental dam was used to isolate the tooth and the canals were accessed with a round diamond bur. The previous composite resin restoration was removed to facilitate the identification of possible cracks. The dentin appeared to be intact, we then proceeded to shape the canals. We started to handfile all canals to a size 15 hand instrument to create a suitable mechanical glide path. In the following sequence all files were pre-bent beginning with HyFlex EDM 10/0.05 (Fig. 9), followed by the EDM OneFile size 25 in a soft pecking motion. Thorough irrigation throughout the treatment helped clear the canals of any debris and necrotic tissue. Gauging the apices revealed ample enough room for a size 30 hand file, indicating that apical enlargement was warranted. The decision was made to utilise EDM 40/0.04 finishing file on the distal canals. Due to the abrupt canal curvature, the mesial canals were shaped using a HyFlex CM 35/0.04. After copious irrigation with NaOCl, EDTA and CHX under acoustic streaming the canals were dried and obturated using the warm vertical compaction technique. Thanks to the flexible, fracture resistant files we were able to shape the canals very effective and efficiently. The access was closed in the same manner as in case 1 (see Fig. 10, 11). Without pre-bendable NiTi files, we would probably have been unable to perform root canal treatment on this tooth.

Size 60 finishing files
In our last case, a 37-year-old female patient presented with a necrotic pulp in the upper right central incisor with an evident vestibular swelling (Fig. 12). The pulp chamber was accessed using a surgical length friction grip size 2 round bur. Once working length was obtained the canal was handfiled to a size 15 hand instrument. Additionally, the HyFlex EDM Orifice Opener 25/0.12 was used to enlarge the coronal aspect of the canal. The apex was gauged, showing that a size 50 hand file was snug. As the canal was already very large coronally, we decided to use a size 60/0.02 EDM finishing file to shape the remainder of the canal and accomplish apical enlargement (cp. Fig. 13). Even the large size 60 EDM file proved its astonishing fracture-resis-
tant quality throughout this case (Fig. 14). The canal was irrigated with NaOCl, dried, calcium hydroxide applied, and sealed with a provisional restoration. To alleviate vestibular swelling incision and drainage was performed.

Three weeks later the patient returned for her follow-up visit. The swelling and I & D site had fully resolved. The root canal system was irrigated, obturated, and sealed as described in the previous cases and the patient was referred back to her general practitioner (Fig. 15). With the aid of the HyFlex EDM files we were able to complete the entire treatment using only two rotary instruments. With this effective system we were able to stay conservative coronally yet enlarge apically. With the right equipment both root canal specialists and general practitioners can create convincing results in a short period of time, without making any concessions to the natural anatomy of the root canal.

Summary

Modular designed NiTi systems demonstrate their full versatility in root canal profiles that are difficult to access or have an unusually abrupt curvature. Flexible files like the HyFlex EDM or HyFlex CM can be pre-bent, which helps dentists to operate both confidently and safely, even under challenging conditions. Depending on the clinical situation endo-specialists can choose between fast instrumentation with only a few files or high-precision shaping of the canal with a clever combination of a more refined file sequence.

Thanks to their intuitive way of handling even newcomers to endodontics can achieve reliable results in next to no time – with an astonishing ‘distal effect’.

contact

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He has given numerous presentations both nationally and internationally and is currently in private practice in Knoxville, Tennessee. Dr Alborz is a member of the American Association of Endodontists, American Dental Association, Tennessee Dental Association, Second District Dental Society and Blount County Dental Society.

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Long-term analysis of primary, non-surgical root canal treatments—A retrospective study

Author: Dr Robert Teeuwen, Germany

Abstract

The aim of this study was to examine more than 8,000 primary, non-surgical root canal treatments in the author’s general practice during 1985–1999 and followed-up for 25 years.

Factors that have influence on failure and extraction rate were evaluated. Statistically, the data were analysed by log-rank test and Cox regression. The estimated survival rates were shown in Kaplan–Meier curves.

With regard to the multivariat Cox regression the significant factors were: overfilled root canal, poor root filling quality, restoration, and fractured canal instrument, via falsa. Further on failure was influenced by the operator and the preoperative status of the pulp. Insurance conditions, patient age and type of tooth influenced the extraction risk.

After 20 years, 82.3% were not subject to failure and 51.5% were saved from extraction.

Introduction

Studies feature the evaluation of factors with the treatment aim of healing and retention in a symptom-free environment. Evaluation of success/failure is partly based on X-rays only, and partly on X-rays plus clinical situation. According to Schmalz, X-rays are not an absolutely reliable parameter. Furthermore, studies show that the bias of the reviewer influences the interpretation of the X-ray. Finally, various improbabilities affect evaluation.

Ng et al. evaluated 76 studies from 1922–2002 in a systematic review. Various studies showed an average success of 74.7% based on strict criteria, and a success rate of 85.2% based on loose criteria. When using strict criteria, the success rate increased with duration of follow-up period—from 67.3% after 24 months to 85.4% after 48 months. In a follow-up publication based on 63 studies, the authors analysed parameters regarding their influence on the success of the root canal treatment (RCT). Using strict criteria, they determined four main factors: apical periodontitis (AP), quality of root canal filling (RF) homogeneous versus non-homogeneous, length of RF, and quality of restoration. They ascribed a success of 82.5% to vital teeth, and a success of 73.1% to non-vital teeth. The lowest success rates could be observed in mandible molars, patient age > 50. In a systematic review of 14 survival studies, Ng et al. showed that survival rates concerning extractions showed better results than success rates. The study of Lee et al. features a clear comparison of the evaluated comparison parameters success/survival.

Materials and methods

The author, who started as a dental practitioner in 1969, used the 9,988 non-surgical endodontic treatment cases registered in his patient files from 1985 to 1999. Of these, X-rays were no longer available in 518 cases. Five teeth were extracted immediately upon noticing of via falsa. Eight hundred and twenty-one cases had not returned to the practice after RCT, however they were included in the dropout rate without further analysis. Thus, 8,644 cases of vital and non-vi-
RCTs were carried out according to the N2-method of Sargenti.9 This method includes the use of the paraformaldehyde-containing zinc oxide root canal cement N2 and canal preparation without canal rinsing. Canal preparation was solely done manually by reamer: using step-back technique in vital teeth, crown-down technique in non-vital teeth. The adequate length of the RF was added in wide canals only. The RF-sitting were always inserted in the apical foramen and cemented N2 composition was applied to the root canal. The RF level was selected as being relevant for the reference to re-intervention: extraction, retreatment (RTR), root-end-resection (RER), trephination (TR), hemisection (HEM). Failures were divided into:

- Diagnosis 1 (success): Regular periodontal gap in all roots
- Diagnosis 2 (uncertain result): AP after < 4 years, incomplete healing, not to be evaluated, scar tissue, remaining shadow around overfilled root-canal;
- Diagnosis 3 (failure): AP still existing > 4 years, newly developed AP, clinical symptoms.

In multi-canal teeth, the root canal with the poorest prognosis was selected as being relevant for the analysis. The present study contains an analysis of success/failure and survival of root-filled teeth with reference to re-intervention: extraction, retreatment (RTR), root-end-resection (RER), trephination (TR), hemisection (HEM). Failures were divided into:

- Clinical failure: no follow-up X-ray accompanying acute exacerbation, pain, swelling, fistula;
- Failure without follow-up X-ray.

The statistic evaluation was executed with proportional hazards analysis. The present study contains an analysis of success/failure and survival of root-filled teeth with reference to re-intervention: extraction, retreatment (RTR), root-end-resection (RER), trephination (TR), hemisection (HEM). Failures were divided into:

- Clinical failure: no follow-up X-ray accompanying acute exacerbation, pain, swelling, fistula;
- Failure without follow-up X-ray.

The statistical evaluation was executed with program R: Core Team.11 The survival rates were estimated by nonparametric estimation according to Kaplan & Meier.12 Group comparison was done by Kaplan-Meier.12 Group comparison was done by

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<tr>
<td>Sympt. preoperative</td>
<td>no</td>
<td>270</td>
<td>257</td>
<td>69.7 (68.2-77.4)</td>
<td>0.116</td>
<td>59</td>
</tr>
<tr>
<td>Pulp preoperative</td>
<td>vital</td>
<td>8086</td>
<td>8000</td>
<td>73.4 (72.1-74.7)</td>
<td>0.186</td>
<td>2385</td>
</tr>
<tr>
<td>Pulp preoperative</td>
<td>non-vital</td>
<td>546</td>
<td>540</td>
<td>71.6 (69.4-73.8)</td>
<td>0.186</td>
<td>115</td>
</tr>
<tr>
<td>Periapex preoperative</td>
<td>lesion</td>
<td>256</td>
<td>250</td>
<td>68.7 (66.4-72.8)</td>
<td>0.0577</td>
<td>56</td>
</tr>
<tr>
<td>Periapex preoperative</td>
<td>no lesion</td>
<td>250</td>
<td>245</td>
<td>67.6 (70.3-83.0)</td>
<td>0.0577</td>
<td>69</td>
</tr>
<tr>
<td>RC-filling length</td>
<td>short</td>
<td>4553</td>
<td>4500</td>
<td>73.5 (71.8-75.1)</td>
<td>&lt;0.0001</td>
<td>1284</td>
</tr>
<tr>
<td>RC-filling length</td>
<td>long</td>
<td>1266</td>
<td>1250</td>
<td>78.2 (74.7-81.2)</td>
<td>&lt;0.0001</td>
<td>375</td>
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<tr>
<td>RC-filling length</td>
<td>flush</td>
<td>760</td>
<td>750</td>
<td>72.3 (68.7-75.9)</td>
<td>0.0001</td>
<td>184</td>
</tr>
<tr>
<td>RC-filling quality</td>
<td>homogen</td>
<td>5788</td>
<td>5750</td>
<td>75.4 (73.7-76.9)</td>
<td>&lt;0.0001</td>
<td>1723</td>
</tr>
<tr>
<td>RC-filling quality</td>
<td>inhomogen</td>
<td>2356</td>
<td>2310</td>
<td>66.6 (64.6-70.3)</td>
<td>&lt;0.0001</td>
<td>767</td>
</tr>
<tr>
<td>Restoration filling</td>
<td></td>
<td>5950</td>
<td>5900</td>
<td>68.2 (65.2-70.8)</td>
<td>&lt;0.0001</td>
<td>1134</td>
</tr>
<tr>
<td>Restoration filling</td>
<td>crown</td>
<td>2482</td>
<td>2450</td>
<td>68.0 (66.4-69.4)</td>
<td>&lt;0.0001</td>
<td>1111</td>
</tr>
<tr>
<td>Restoration crown-root</td>
<td></td>
<td>1285</td>
<td>1250</td>
<td>68.4 (69.3-80.1)</td>
<td>&lt;0.0001</td>
<td>146</td>
</tr>
<tr>
<td>Restoration filling-root</td>
<td></td>
<td>575</td>
<td>570</td>
<td>56.1 (54.1-57.8)</td>
<td>&lt;0.0001</td>
<td>295</td>
</tr>
<tr>
<td>Breakage RC-instrum.</td>
<td>yes</td>
<td>382</td>
<td>378</td>
<td>56.4 (53.9-59.7)</td>
<td>&lt;0.0001</td>
<td>93</td>
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<tr>
<td>Breakage RC-instrum.</td>
<td>no</td>
<td>6262</td>
<td>6200</td>
<td>73.7 (72.4-75.8)</td>
<td>&lt;0.0001</td>
<td>2417</td>
</tr>
<tr>
<td>Molar size</td>
<td>yes</td>
<td>32</td>
<td>31</td>
<td>72.6 (62.1-83.4)</td>
<td>&lt;0.0001</td>
<td>2</td>
</tr>
<tr>
<td>Molar size</td>
<td>no</td>
<td>8812</td>
<td>8800</td>
<td>73.4 (72.2-74.7)</td>
<td>&lt;0.0001</td>
<td>2508</td>
</tr>
</tbody>
</table>

Table 1: Survival probability related to extraction and failure with confident intervals (CI).
study non-surgical treatment

Log Rank test. A p-value of < 0.05 was judged as being significant statistically. Survival publications depending on 14 influence factors (Table 1) in reference to failure and extraction were determined with the help of the multiple Cox regression (Table 2). This include the findings which were relevant in vital and non-vital cases.

Results

The observation period of the 8,644 analysed teeth lasted up to 25 years after the RCT (median 6 years). 8,098 (93.7 %) were attributed to vital extirpations (VitE) and 546 (6.3 %) to conservative initial treatment of non-vital teeth. During the observation pe-

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sub-Group</th>
<th>Extraction p-Value</th>
<th>HR</th>
<th>CI</th>
<th>Failure p-Value</th>
<th>HR</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator</td>
<td></td>
<td>0.013</td>
<td>1.210</td>
<td>1.041-1.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insurance</td>
<td>(RVO reference)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VDAK</td>
<td>&lt;0.001</td>
<td>0.767</td>
<td>0.69-0.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private</td>
<td>&lt;0.001</td>
<td>0.759</td>
<td>0.65-0.88</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>(&lt;30 reference)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-50</td>
<td>&lt;0.001</td>
<td>1.874</td>
<td>1.66-2.11</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>&gt;50</td>
<td>&lt;0.001</td>
<td>3.123</td>
<td>2.75-3.55</td>
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<td></td>
</tr>
<tr>
<td>Tooth-type</td>
<td>(front reference)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>premolar</td>
<td>0.001</td>
<td>0.815</td>
<td>0.73-0.91</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>molar</td>
<td>&lt;0.001</td>
<td>0.731</td>
<td>0.64-0.84</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulp preop.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r.c. filling length</td>
<td>(short reference)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>flush</td>
<td>0.099</td>
<td>0.914</td>
<td>0.82-1.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>long</td>
<td>0.026</td>
<td>0.818</td>
<td>0.69-0.96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r.c. filling quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.004</td>
<td>1.160</td>
<td>1.05-1.28</td>
<td>&lt;0.001</td>
<td>2.081</td>
<td>1.78-2.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restoration</td>
<td>(filling reference)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>crown</td>
<td>&lt;0.001</td>
<td>0.310</td>
<td>0.20-0.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>crown+ post</td>
<td>&lt;0.001</td>
<td>0.316</td>
<td>0.26-0.39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure</td>
<td></td>
<td>&lt;0.001</td>
<td>2.794</td>
<td>2.49-3.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breakage canal instr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Via falsa</td>
<td>&lt;0.001</td>
<td>2.533</td>
<td>1.60-4.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CI = Confidence Interval
Factors are compared with the reference group based on value 1.
Hazard Ratio >1: the evaluated factor has a greater risk of a negative result
Hazard Ratio <1: the evaluated factor is less prone to a negative result
period, an average of 5,295 cases attained a minimum of one follow-up X-ray after 7.14 years: 4,886 (60.3%) in vital teeth, 409 (74.9%) in non-vital teeth. The follow-up X-ray diagnoses are shown in Table 3.

X-ray diagnosis < 4 years after RCT (n = 1,482) revealed a radiographical failure of 9.9%. This radiographical failure rate decreased to 8.3% when diagnosis was made > 4 years after the RCT.

Out of the entity of 713 failures (8.2% of all RCTs), 514 (5.9% of all RCTs) were incorporated with X-ray. In doing so, the failure of 465 cases (90.5%) was proved radiographically; 49 failures (9.5%) were not substantiated in the X-ray. Another 199 cases (2.3% of all RCTs) in form of acute exacerbations had to be judged as clinical failures without follow-up X-ray: 139 (1.72%) in vital, 60 (10.98%) in non-vital teeth. Fifty-five failures remained without therapy. In 13 cases, therapy was limited to a non-contact grinding. Four hundred and twelve failures (57.8%) were extracted, failures increased extraction rate to the 2.8-fold.

Fourteen factors had been evaluated (Table 1) regarding extraction and failure rate. Five of these factors (operator, vitality status prior to RCT, preoperative AP, preoperative symptoms, number of appointments) did not have a significant influence to the extractions statistically, whereas three factors (sex, insurance condition, preoperative symptoms) did not have a significant influence to failure.

Of the RCTs, 58.7% were carried out by the author himself, and 41.3% by his assistant doctors. Cox regression showed a higher failure risk for the assistant cases versus the author: however, there was no higher extraction risk.

The clientele consisted of 51.4% male and 48.6% female patients. Regarding failures and extractions, a significant statistic difference between the sexes could not have been observed in the multivariate analysis (p = 0.417).

With regards to insurance, 59% of the patients were insured by the RVO health insurances (legal health insurance for workers), 26.6% by insurances for employees, 12.6% had private health insurance, and 1.7% were insured elsewhere. The failure analysis revealed no difference between the individual insurances (p = 0.629). Cox regression showed a lesser (approx. 24%) extraction risk in employees and privately insured patients.

The average age of the patients amounted to 36.7 years (6–84). Regarding age, the highest failure rate was observed in patients < 30 years, however, they had the lowest extraction rate. According to Cox regression, the middle age group of

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Total</th>
<th>%</th>
<th>Vital</th>
<th>%</th>
<th>Non-vital</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Success</td>
<td>4474</td>
<td>84.5</td>
<td>4171</td>
<td>85.4</td>
<td>303</td>
<td>74.1</td>
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<tr>
<td>Uncertain</td>
<td>356</td>
<td>6.7</td>
<td>304</td>
<td>6.2</td>
<td>52</td>
<td>12.7</td>
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<tr>
<td>Failure</td>
<td>465</td>
<td>8.8</td>
<td>411</td>
<td>8.4</td>
<td>54</td>
<td>13.2</td>
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<tr>
<td></td>
<td>5295</td>
<td></td>
<td>4886</td>
<td></td>
<td>409</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Follow-up X-ray-diagnosis.
30–50 years had nearly 2-fold and the age group of over 50 years a 3.1-fold higher extraction risk versus the patients under the age of 30.

Analysis revealed significant differences (< 0.0001) regarding failures connected with the kind of tooth: molars 18.2 %, premolars 8.8 %, front teeth 8.1 %. Extraction rate of upper incisors was the lowest, extraction rate of the lower incisors the highest. Details can be seen in Table 4. According to univariate analysis, age and kind of tooth were not relevant regarding failure. Considering all analysed influence factors, premolars had a lower extraction risk of 81.5 % versus front teeth, molars a lower extraction risk of 73.1 %.

Aside from 19 teeth (0.23 %), all vital teeth were treated in one appointment. The multi-appointment of non-vital teeth in 257 cases (47 %) led to more failures (p = 0.0496). Significant failure rate differences could be observed regarding pulp vitality prior to RCT (p < 0.001). Cox regression showed the significantly lower failure risk for vital teeth, which amounted to 30.9 % of non-vital teeth.

Two hundred and fifty-six (46.9 %) of the non-vital teeth featured an apical lesion when starting RCT. These were diagnosed with a failure rate of 34.9 %

### Table 4: Survival probability of teeth-groups 10 years after root-canal-treatment (p-value compared to the totality of all other teeth).

<table>
<thead>
<tr>
<th>Teeth At Risk</th>
<th>Extraction Survival (CI)</th>
<th>Failure Survival (CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>P</td>
</tr>
<tr>
<td>12,11,21,22</td>
<td>346</td>
<td>81.9 (78.9-85.1)</td>
</tr>
<tr>
<td>13.23</td>
<td>242</td>
<td>71.8 (67.7-76.2)</td>
</tr>
<tr>
<td>14,15,24,25</td>
<td>478</td>
<td>72.3 (69.3-75.4)</td>
</tr>
<tr>
<td>16,17,18,26,27,28</td>
<td>372</td>
<td>72.3 (69.1-75.7)</td>
</tr>
<tr>
<td>32,31,41,42</td>
<td>68</td>
<td>63.1 (55.6-71.5)</td>
</tr>
<tr>
<td>33.43</td>
<td>200</td>
<td>69.3 (64.8-74.1)</td>
</tr>
<tr>
<td>34,35,44,45</td>
<td>591</td>
<td>74.6 (72.0-77.4)</td>
</tr>
<tr>
<td>36,37,38,46,47,48</td>
<td>362</td>
<td>70.9 (67.7-74.4)</td>
</tr>
<tr>
<td>36,46</td>
<td>174</td>
<td>72.2 (67.6-77.0)</td>
</tr>
</tbody>
</table>
| 37,47         | 163                       | 69.7 (64.7-75.0)       | 0.197         | 157                       | 84.7 (80.7-88.9)       | 0.0175                 

### Case 1

**Figs. 5a & b**: Pre-op X-ray (a). Post-op X-ray with fistulation drill (b).

**Figs. 6a & b**: Fistulation drill in situ (a). Post fistulation (b).

**Fig. 7**: Control X-ray—5 years after treatment.
after 10 years. The difference with/without AP was significant (p = 0.0028 %).

Also RF-degree (Fig. 1), RF-quality and restoration had a significant influence on the failure rates. The highest failure frequency could have been observed after overfilling. Adequately filled teeth had a risk of failure of 63.6 % versus underfilled teeth; overfilled teeth had a 1.8-fold higher risk in comparison to underfilled teeth. Extraction rates of adequately and underfilled teeth featured nearly the same extraction frequency, whereas overfilled teeth showed an extraction risk of 18 % less. 25 % of all front teeth and premolar RFs as well as 52.6 % of all molar RFs showed a poor RF-quality which ended in a twofold failure risk versus a good RF quality and thus a 16 % higher risk of extraction (Fig. 2).

Root-filled teeth provided with one filling only had a higher tendency to failures and extractions. Cox regression proved a failure rate of 28 % less after crowning with build-up pins versus filling therapy. Without build-up pin insertion, crown provision was the reason for a 57 % lower failure rate. Crowning reduced the extraction risk to 31 % of teeth provided with a filling.

Table 5: Re-intervention of all RCT and failure of re-intervention.

<table>
<thead>
<tr>
<th>Re-intervention</th>
<th>n</th>
<th>%</th>
<th>Failure</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction</td>
<td>1883</td>
<td>21.78</td>
<td>412</td>
<td>21.87</td>
<td></td>
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<tr>
<td>RER</td>
<td>82</td>
<td>0.95</td>
<td>79</td>
<td>96.34</td>
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<tr>
<td>RTR/RER</td>
<td>47</td>
<td>0.54</td>
<td>43</td>
<td>91.48</td>
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</tr>
<tr>
<td>RTR/TR</td>
<td>12</td>
<td>0.14</td>
<td>11</td>
<td>91.66</td>
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</tr>
<tr>
<td>RTR</td>
<td>90</td>
<td>1.04</td>
<td>35</td>
<td>38.88</td>
<td></td>
</tr>
<tr>
<td>TR</td>
<td>58</td>
<td>0.67</td>
<td>58</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>HEM</td>
<td>10</td>
<td>0.11</td>
<td>7</td>
<td>70.00</td>
<td></td>
</tr>
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<td></td>
<td>2182</td>
<td>25.24</td>
<td>645</td>
<td>29.56</td>
<td></td>
</tr>
</tbody>
</table>

RER = root-end resection
RTR = retreatment
TR = trephination
HEM = hemisection

Cox regression by finding a 32 % higher extraction risk (Fig. 3).

The process-related accident of a via falsa with perforation increased failure rate (75.2 % failure rate after 8 years) to the 8.4-fold, extraction risk to the 2.5-fold.

Extractions represented the main contingent of re-interventions with another 299 treatments (RER, RTR, TR, HEM). Nearly 30 % of re-interventions were needed due to failure. The relation of re-intervention and failure can be learned from Table 5. Table 6 gives a survey about reasons for extraction and their relation to failures. Figure 4 shows the chance of survival of cases which were not subject to extraction, further re-interventions or failure (clinically, radiologically) in a survival curve according to Kaplan Meier. After 20 years, 82.3 % (CI 80.5 84.2) of RCTs were not affected by radiological and/or clinical failure with n = 381 remaining under risk. Within the first year after RCT the incidents were: 183 of the 199 (92 %) acute exacerbations, 22 of the 514 (4.3 %) failures with follow-up X-ray, 159 of the 1,883 (8.4 %) extractions and 140 of the 299 (46.8 %) further re-interventions.

Discussion

‘Presence or absence of the tooth is not subject to interpretation as would be subjective measurement of radiographic change, clinical signs and symptoms, patient history, etc.’ With this statement, Alley et al. pointed out the advantages of survival studies, whereas Torabinejad et al. limited these advantages by calling survival studies as being ‘less biased’ as well as less informative. They further noted that endodon-
tic studies come up with another variability making comparability more complicated.

The cases of the present study were treated in the authors office and evaluated by the author himself. Whereas extraction and thus the relevant survival represent a hard, non-discussible fact, success/failure evaluations are subject to bias. According to literature\textsuperscript{6,7} the survival rate regarding tooth extractions is higher than the failure rate. Analysis of the practice data showed the opposite: after 20 years, 51.5\% of the teeth were still in situ and 82\% were still saved from failure.

Comparison with some studies can partly not be made, as survival data refer to the initial case numbers and are not in reference to the remaining cases getting less over the years. So the survival dates referring to extractions gained from the insurance registers have to be seen critically. Lazarski et al.\textsuperscript{15} indicated that 94.4\% remained in the mouth functionally after an average of 3.5 years. Salehrai and Rotstein\textsuperscript{16} calculated a remaining in situ of 97.1\% after 8 years and Chen et al.\textsuperscript{17} a remaining in situ of 93.3\% after 5 years. Drop-outs are not mentioned in these studies. The fact is that only data known to the insurance are evaluated in those studies, which is rather unlikely in non-treated pathology, non-treated radiographical failure or goodwill treatments. In 914 cases, Stoll et al.\textsuperscript{18} noticed 105 (11.5\%) losses [extractions, RER, RTR] after 106 months, which can be interpreted as a cumulative survival rate of 74\%. De Chevigny et al.\textsuperscript{19} report about 70–73\% of drop-outs. They judged the remaining cases as being in function (95\%) and as healed radiographically (86\%).

The present study includes a drop-out rate of 40.6\% after 5 years, of 58.5\% after 10 years. As a recall never took place it can be supposed that the drop-out rates would have been more favorable in case of recall management.

The long observation period of up to 25 years may have supported the low failure rate. The later lower failure rate can be led back to the fact that the radiographical failure diagnosis averaged from 9.9\% to 8.3\% after the fourth year. It has to be mentioned that 9.5\% of the failures accompanied by X-ray could not have been verified radiographically. This may be due to the fact that the apical osteitis has not yet rounded the corticalis with sufficient mineral loss what is, according to Bender\textsuperscript{20}, the pre-condition for a radiographical AP presentation. Also anatomic features may superimpose an AP. The declining development of apical lesions over time.

<table>
<thead>
<tr>
<th>Extraction Reason</th>
<th>Extraction n</th>
<th>Failure n</th>
<th>Extraction %</th>
<th>Failure %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caries, Fracture</td>
<td>866</td>
<td>55</td>
<td>46</td>
<td>6.4</td>
</tr>
<tr>
<td>Parodontopathy</td>
<td>441</td>
<td>24</td>
<td>23.4</td>
<td>5.4</td>
</tr>
<tr>
<td>Prosthetics</td>
<td>167</td>
<td>10</td>
<td>8.9</td>
<td>6</td>
</tr>
<tr>
<td>Endodontic Failure</td>
<td>222</td>
<td>222</td>
<td>11.8</td>
<td>100</td>
</tr>
<tr>
<td>Unknown Reason</td>
<td>78</td>
<td>4</td>
<td>4.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Pain</td>
<td>109</td>
<td>97</td>
<td>5.8</td>
<td>89</td>
</tr>
<tr>
<td>Total</td>
<td>1883</td>
<td>412</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Extraction reason and failure.
conforms to literature data indicating a better RCT success result\textsuperscript{1,2} although Eckerbom et al.\textsuperscript{22} noted an increase of apical lesions from 17.3\% to 21.4\% within 20 years. The own, relatively high success rate might be based on a bias with a too positive evaluation of the cases or an over-representation of the VitEs. It might also be due to the used RCT method as observed in epidemiological studies\textsuperscript{23} in countries with extensive application of formaldehyde-containing materials despite poor technical RF-quality.

Socially advantaged patients were represented with approx. 40\% in the examined patient population. They carried a 24\% lower extraction risk than social weak patients. A different failure risk did not exist between the individual social statuses of the patients. According to Hujoel et al.\textsuperscript{24}, decision for extraction is determined by sociodemographic factors. A low income status and a low level of education favor the decision for extraction. The authors Jafarian and Etebarian\textsuperscript{25} concluded from an analysis of 2,620 extracted teeth that the level of education is of significant importance for tooth preservation. In a company health insurance study\textsuperscript{26} representing the working class, 8.3\% of the endodontic cases were extracted within 2 years. After 5 years, 28\% of reinterventions in the form of extractions and RTRs became necessary. In my own practice, the cumulative survival rate of all reinterventions increased to 16\% after 5 years.

According to Lee et al.\textsuperscript{7}, the median survival limit regarding extraction had been reached after 21 years, thus approximately corresponding to my own. The median failure limit of Lee et al. was after 119 months (about 10 years). It has to be added that the authors scheduled their study 2 weeks after RCT only, so very early extractions and failures might have been skipped from the study.

Torabinejad et al.\textsuperscript{14} pointed out that in their study they categorically assigned pain after RCT to the failures. The same principle is valid for the present study. All acute exacerbations (clinical failures) were treated. 10.5\% of the failures accompanied by X-ray did not undergo therapy. The postoperative pain sensations amounted to 1.7\% after vital, after completion of a non-vital treatment to 11\%. A little more than a third could be contributed to overfilling: 30.9\% after overfilling of vital and 41.7\% after overfilling of non-vital teeth. The Gesi et al.\textsuperscript{27} study on vitally extracted teeth mentions a pain rate of 13.3\% within the first week after VitE. 30.7\% of the pain arose in overfilled teeth. In the own study, 69 overfillings (34.2\%) were responsible for 199 postoperative pain sensations.

Neither the sex, nor the preoperative pathology or the number of appointments were decisive for extractions or failure. However, the failure risk of vital teeth only amounted to 30.9\% of non-vital teeth. The multivariate analysis emphasised the results of the univariate analysis regarding the extraction risk subject to age and kind of tooth. The two older age classes attained higher extraction rates compared to the age class of <30. With increasing age, tooth loss rises even in non-root canal treated teeth by carious destruction and periodontal diseases. According to Eriksen et al.\textsuperscript{23}, epidemiologic studies reflect the endodontic performance of general dentists with success rates of 60–75\%. In his own practice, the author achieved a failure rate of 10.3\% in vital and 28.7\% in non-vital teeth.

It is also to be expected that different levels of experience are responsible for different success rates. The cases treated by assistant doctors had a statistically significantly higher failure rate compared to the practice senior while the extraction rates of assistants and practice senior were on the same level. Cox regression proved that RF-degree and RF-quality do hardly play a role for the extraction risk the more however for the failure risk. An RF with ‘voids’ and incomplete canal wall adhesion allows a bacterial augmentation/invasion, an overfilling at least a periapical irritation caused by canal content flowing over the apex and root canal filling material.

According to Ng et al.\textsuperscript{6}, the most significant criteria for survival were: crown, two proximal contacts,
no use as prosthetic post and non-molar. In their studies, crowned teeth with or without build-up pin showed the lowest extraction risk versus all other researched variables, crowned teeth without build-up pin simultaneously featured the lowest failure risk. Crowns offer a high fracture protection and are an expensive investment, where the patient does not like to separate from. It has to be considered though that crowning of teeth is preceded by an estimation of the survival prognosis and the better case material will be considered first when it comes to crowning.

Regarding the incidents of perforation and fractured canal instrument, the author found evidence from Ng et al. in the survival literature, where 76 (4.7%) of 1,617 cases were subject to perforation and 105 cases (12.2%) out of 858 secondary root canal treatments subject to fracture of a canal instrument. The Cox regression proves a 3.7-fold extraction risk for perforations, for the cases with fractured canal instrument a 3.1-fold extraction risk. Marquis et al. added 11 fractured canal instruments and 18 perforations in 369 endodontic cases to the intraoperative complications which affect the success result. Their own study proved a 2.5-fold extraction and a 8.4-fold failure risk for via falsa perforations. In case of fractured canal instruments the risk of extraction increased 1.3 times and the risk of failure to 2.2 times.

**Conclusions**

More than 8,000 endodontic primary cases had been observed for up to 25 years. Quality and length of RF, the type of restoration, the fracture of root canal instruments and the incident of perforation were responsible for the failure and extraction risk. The position of the tooth, age and social status had an influence on extraction frequency, the pulp state and the operator on the failure frequency. A symptom-free tooth remaining in situ of 73.2% after 10 years and 51.5% after 20 years speaks for a successful endodontic treatment therapy under practice conditions.

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Editorial note: A list of references is available from the publisher.

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FKG Dentaire SA expands its range of 3-D instruments with the introduction of the XP-endofinisher R

FKG Dentaire SA continues its marketing of innovative instruments, after the introduction of the revolutionary XP-endofinisher in 2015. The range of instruments designed for 3-D cleaning of the root canal is now enriched by the XP-endofinisher R (XP-FR), targeting the removal of filling material. Made of a unique and highly flexible NiTi alloy that can expand 100 fold compared to standard instruments, XP-FR reaches areas of the canal walls impossible to reach with traditional files. After initial filling material is removed, regardless of the instrumentation technique used, residual material is always present particularly in curved or oval canals. Like with the XP-endofinisher the exclusive FKG MaxWire alloy (Martensite-Austenite) gives to the instrument the ability to expand and contract so as to contact difficult to reach areas, especially in curved- and oval-shaped canals. With its ISO 30 diameter, the XP-FR is slightly stiffer than the XP-endofinisher enabling it to eliminate Gutta-percha and sealer. Moreover, the XP-FR features unparalleled resistance to cyclic fatigue, due to its small core size and zero taper. The instrument is easy to use and intended for all dentists keen to enhance the long-term success of their retreatment procedures.

The XP-FR is available in sizes 21 and 25 mm, packed in a sterile blister of 3 instruments. For more information please visit FKG website.

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Vista Dental Products is revolutionizing composite delivery with its new line of Therma-Flo products, which the company says are uniquely engineered to utilize heat for optimal performance of any preferred composite material. The Therma-Flo Composite Warming Kit is designed to improve the flowability of highly filled composites more than 100 percent through the use of heat. With the Therma-Flo Warming Kit, your preferred highly filled composite will perform like a flowable, providing greater adaptation to the cavity walls, according to Vista.

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Therma-Flo Composite Warming Kit

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Premier global forum for endodontics takes place in Dubai

This year’s ROOTS SUMMIT, which has drawn dental professionals to various locations all over the world in the past decade, will take place from Nov. 30 to Dec. 3 at the Crowne Plaza Dubai hotel in the United Arab Emirates. Aimed at updating participants about the latest in endodontic treatment, an unparalleled series of lectures and workshops will be held by global opinion leaders in the field.

Although the meeting will focus exclusively on the latest techniques and technologies in endodontics, the organisers have strongly encouraged not only dentists specialising in the field to attend but all who have an interest in endodontics, including general dentists and manufacturers and suppliers of endodontic products. Overall, about 700 attendees are expected.

Over the past 15 years, the ROOTS SUMMIT has grown significantly. The community originally started as a mailing list of a large group of endodontic enthusiasts in the 1990s. After the establishment of a dedicated Facebook group three years ago, membership increased from 1,000 to more than 20,000. Today, the group is composed of members from over 100 countries.

Previous ROOTS SUMMITS have been held in Canada, the US, Mexico, Spain, the Netherlands, Brazil and last year in India. These meetings have been known for the strength of their scientific programs and their relevancy to clinical practice. The lectures, workshops and hands-on courses scheduled for this year’s meeting will be no exception. More than 15 distinguished experts are presenting during the conference.

For the summit in Dubai, the organisers have partnered with Dental Tribune International (DTI) and the Dubai-based Centre for Advanced Professional Practices (CAPP) for the first time. With its international network, composed of the leading publishers in dentistry, DTI reaches more than 650,000 dental professionals in 90 countries through its print, online and educational channels, as well as a number of special events.

Over the past decade, CAPP has been able to establish first-class standards for continuing dental education programs not only in the UAE but also across the Middle East. Since 2012, CAPP has been affiliated with DTI as a strong local partner in the Middle East.

Based on the successes of previous ROOTS SUMMITS, the organisers anticipate a large turnout for this year’s meeting. Various sponsorship opportunities are available, including booth space, as well as sponsorships of workshops, hands-on courses, meeting bags and social events.

Online registration for the ROOTS SUMMIT is now open at www.roots-summit.com. Dental professionals are also invited to join the ROOTS Facebook group and like the ROOTS SUMMIT 2016 Facebook page.
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