Minimally invasive endodontics

Sebastian Bürklein, Dr med dent¹/Edgar Schäfer, Prof Dr med dent²

Minimally invasive endodontics (MIE) aims to preserve the maximum of tooth structure during root canal therapy. In the last 15 years there has been rapid progress and development in endodontics, making treatment procedures safer, more accurate, and more efficient. Meanwhile, reproducible results can be achieved even in difficult root canal morphologies with severe or double curvatures. In addition to various material improvements, the implementation of the surgical microscope (SM) in endodontics is an important innovation, making it possible to optimize each step in the treatment protocol in terms of substance preservation. (Originally published in Quintessenz 2014;65:565–570; Quintessence Int 2015;46:119–124; doi: 10.3290/j.qi.a33047)

Key words: endodontics, minimally invasive endodontics (MIE), preservation of tooth structure, surgical microscope

Successful root canal treatment depends on many factors. Up to now, most individual steps during root canal treatment are carried out without a direct view into the entire root canal system, especially in curved canal systems. Manual tactility in conjunction with a diagnostic radiograph mainly represents the sole basis of the treatment. This raises the question of whether improved visibility leads to better preservation of tooth structure or if it is more likely associated with greater substance weakening.

LIMITS OF THE HUMAN EYE

The better the spatial resolution or visual acuity of eyes, the smaller the distance between two separate points or lines that can still be perceived as separate. The resolution of the human eye is about 0.2 mm. However, numerous treatment steps in endodontics require accuracy well below the resolution the human eye can differentiate without an optical aid. With a surgical microscope the resolution can be increased to up to 6 μm (Fig 1). Thus, magnification is an almost indisputable condition for implementing minimally invasive procedures.

MINIMALLY INVASIVE ENDODONTICS

In each step of root canal treatment including diagnosis, the decision-making process, the design of endodontic access cavity, instrumentation of the root canals, or even apical surgery (Fig 2) or surgical crown-lengthening, minimally invasive strategies will probably supersede more invasive methods. Nevertheless, knowledge of the exact anatomical structures and their variations is decisive for the individual treatment steps. As part of the root canal treatment, the aspects listed below offer the option to implement a minimally invasive therapy.
Access cavity

The design of the access cavity is crucial to maintain healthy tooth structure (Figs 3 and 4). A diagnostic radiograph to display the anatomy of the tooth and morphology of the root canals is a prerequisite to prepare minimally invasive access cavities as it provides a first orientation concerning the localization of the pulp chamber and the root canals. However, before access cavity preparation, insufficient coronal restorations and caries lesions should be removed and a pre-endodontic restoration performed to minimize the risk of recontamination of the endodontic system during treatment procedures.

The preparation of the access cavity can be divided into three steps:1

- Primary access cavity: Cleaning the whole pulp chamber including complete removal of hard tissues that may impede the straight line access to the root canals represents the first step. The differentiation of tertiary dentin (normally colored differently compared to regular dentin) is only achievable with good illumination and after drying the cavity. Magnification aids (eg, surgical microscope or magnifying glasses) facilitate the procedure. Fine diamond-coated or non-diamond-coated ultrasonic tips allow a careful dissection along the recognizable boundaries. This gentle and fine preparation can usually be performed without the water cooling that hinders clear visibility.
- Secondary access cavity: The number of root canal orifices in a particular tooth can never be known prior to the commencement of the treatment. Hence, canal orifices should be identified with the utmost care. With the exception of single-rooted teeth, canal orifices are never localized in the center of the pulp chamber but always at the junction of the dark horizontal floor and the lighter vertical walls of the pulp chamber. Consequently, a clear identification of the floor-wall junction is one of the important aspects of the accessing phase of root canal treatment. Useful methods to find the orifices are staining with erythrosine or methylene blue, translumination of the tooth with a polymerization or cold light lamp, and gentle probing with a sharp probe. Micro-instruments facilitate this procedure and guarantee optimal preservation of healthy tooth structure (eg, pilot instruments, orifice opener, micro-debrider, or engine driven files). In particular, forced use of Peeso reamers and Gates Glidden drills is often associated with excessive material removal in the coronal portion of the root canal (Fig 5).
- The chemomechanical preparation of the root canal system is the next step and should usually start with the creation of a glide path that can be prepared either with hand instruments or with engine driven rotary path files.
The use of cone beam computed tomography (CBCT) with its superimposition-free three-dimensional pictures reconstructed with mathematical algorithms from multiple projections provides further information concerning root anatomy, resorptions, root fractures, and other complications like perforations or even fractured instruments for treatment planning compared to conventional two-dimensional periapical radiographs. However, a CBCT-based design of the access cavity seems not to be associated with an improved preservation of sound tooth structure in teeth without special anatomical root morphologies.2

**Root canal preparation**

**Influence of tapered instruments**

Proper chemomechanical disinfection of the canal system is crucial for the success of the entire root canal therapy, but irrigation of the apical portion of the root canal is challenging. To achieve sufficient irrigation over the entire length of the root canal, a preparation of at least size 40, taper .04 is required. According to some clinical studies this size represents an ideal compromise between efficiency of irrigation and treatment-related root dentin weakening, particularly when irrigation is activated (eg, passive ultrasonic irrigation (PUI)).46 In curved canals an apical preparation size of...
size 40, taper .06 is proposed to guarantee proper irrigation in the apical part.

According to these requirements, the latest micro-CT studies of the original taper of various root canals showed that the functional taper (over the entire canal length) in maxillary molars is about 1.5% in the buccal root canals and 6.2% in the palatal root canal. In particular, concerning the treatment of noninfected root canals (vital extirpation) this raises the question of the necessity of excessive material removal caused by the use of instruments with greater tapers. Namely, it is known that a reduced taper of instruments is correlated with an increased fracture resistance of root canal treated teeth, as remaining structural integrity is known to have an important impact on the long-term survival rate after adequate coronal restoration of root canal treated teeth.

So far, these considerations are of clinical relevance because each root canal treatment is associated with a significant weakening of the tooth structure (crown and root). The fracture resistance of a root canal treated tooth is directly correlated with the amount of remaining sound tooth structure. Currently, manual root canal preparation with ISO standardized instruments (taper .02) appears to be associated with a lower weakening of the tooth compared to rotary preparation. The self-adjusting file (SAF, Redent Nova) allows very substance-preserving preparations with significantly lower dentin removal than allowed by root canal preparation using rotary nickel-titanium instruments. In addition, when using these instruments reduced stress induction is described on the remaining residual dentin.

The SAF is a compressible diamond-coated titanium mesh with a roughness of 2.8 μm ± 10%. Due to its compressibility this hollow file adapts with circumferential pressure to the canal walls and removes in about 4 minutes 250 μm of dentin from the touched canal walls using 5,000 vibrations per minute combined with a vertical amplitude of 0.4 mm. Continuous and simultaneous activated irrigation of the root canal system is performed with an adjustable amount of 1 to 10 mL/min that is directly transported inside the hollow file by a special device.
Influence of instrument design
The flexibility of each root canal instrument decreases with increasing core diameter, regardless of its design and alloy. Consequently, the straightening tendency is more pronounced when enlarging severely curved canals to a greater apical preparation size. Nickel-titanium (NiTi) instruments have some distinct advantages compared to stainless steel files as they are claimed to maintain the original canal curvature better during root canal preparation due to their increased flexibility. Based on recent developments in metallurgy and the introduction of new alloys in endodontics (M-wire, CM-wire), new instruments have become available (eg, Hyflex CM, Coltène/Whaledent; Twisted Files, SybronEndo; ProTaper NEXT, Dentsply Maillefer) that possess improved root structure preserving effects.15,22

Currently, each root canal preparation technique seems to be associated with the induction of dentinal damage/defects. Both rotary as well as reciprocating mechanical root canal instrumentation may cause micro-cracks or other dentinal damage (Fig 6).14 Although the reciprocal movement (cutting of the instruments in counterclockwise direction, and releasing in clockwise direction) reduces the torsional and cycling stresses on the instruments and thus the risk of instrument separation is minimized, instruments used in this working motion seem to induce more dentinal micro-cracks than rotary instruments.14 However, manual instrumentation with less tapered (2%) hand instruments produces significantly less incomplete and complete micro-cracks compared to mechanical preparation techniques.13

Obturation techniques are also associated with dentinal damage.23 Hence each endodontic procedure may ultimately lead to a loss of tooth structure and finally may contribute to partial or complete root fractures, despite the primary intention of preservation. Vertical root fractures (VRF) are one of the most serious complications during or after root canal treatment24,25 and are associated with severe clinical problems for both the patient and the dentist.26 Therefore, it is crucial to establish a compromise between further simplifying root canal preparation and obturation by using modern techniques (especially with respect to thermoplastic obturation) and the resulting weakening of tooth structure (Fig 7). The iatrogenically induced causes of fractures in root canal treated teeth (loss of tooth structure, effects of chemical agents [irrigants and intracanal dressings], and restorative procedures) can be influenced and minimized by the dentist, whereas non-iatrogenic causes cannot yet be influenced (ageing of tooth structure, the anatomy of the tooth and its position in the jaw, and masticatory forces).

CONCLUSION
Minimally invasive endodontics is desirable in the interest of the patient, and preserving tooth structure requires optical magnification aids (surgical microscope), ultrasonic-assisted preparation techniques, modern file systems, and in-depth knowledge of the tooth and root canal anatomy. However, as yet there is no clear evidence concerning the impact of MIE on the success rate.
REFERENCES