New insights into the root canal wall

Introduction

Endodontology is concerned with the study of the form, function and health of, injuries to and diseases of the dental pulp and periradicular region, and the prevention and treatment of apical periodontitis, caused by infection (European Society of Endodontology, 2006). The technical aim of the endodontic treatment is the shaping and cleaning of the root canal system and the filling of the canals as if to prevent coronal leakage and entomb remaining microorganisms, preventing them from irritating the periapical tissues (Sundqvist *et al.*1998). Recent evidence show that endodontic therapy may not always result in favorable and predictable outcomes. Moreover, it seems that clinical endodontic research often failed to address important issues concerning the success rate of the treatment (Wu *et al.* in print).

In order to investigate the effectiveness of procedures during endodontic therapy, two major approaches could be taken: randomized clinical studies comparing the results of treatments and *in vitro* investigations. Randomized clinical studies have a higher level of evidence when compared to other studies but are difficult to perform not only because of the need to standardize conditions but also because experimenting on human beings requires a set of preconditions which is nowadays hard to meet. When human subjects are difficult to investigate and control, animals may provide more relevant information on the outcomes of different treatments. Experimenting with animals is controversial in most countries and strict rules and pre requirements make these investigations time consuming and expensive. The next step when coming to think about an investigation method is *in vitro* studies. These laboratory tests aim at investigating different materials and methods in laboratory conditions using models, extracted teeth and special machinery. The common substrate for all endodontic procedures is the root canal itself, but different aspects of the root canal treatment from the root canal wall perspective were seldom addressed. Root canal treatment is roughly divided into two important steps: mechanical instrumentation and filling of the root canal. Both pose challenges to the clinician and researcher while there is currently no consensus as to the preferred method or material of choice.

Preparation and instrumentation of the root canal

The objective of mechanical instrumentation is to remove the main bulk of infected material and its nutritional supply and to prepare the canal for the filling procedure (Hülsmann *et al.* 2005). There are numerous problems associated with the preparation procedures and their effect on the root canal walls:

1. A debate exists as to the formation, importance and faith of the smear layer which is caused during the preparation procedures (Sen *et al.* 1995). This thesis addresses this debate in a few studies checking the influence of the removal of the smear layer on the effectiveness of the filling and the propagation of light through the dentinal tubules.

2. In infected root canals microorganisms could be attached to the root canal walls in the form of biofilms (Svenssater & Bergenholtz 2004, Chavez de Paz 2007) which are more resistant to cleaning procedures and disinfectants. Biofilms are difficult to image and investigate, and existing investigation methods involve preparation procedures that could damage the biofilm structure and vitality. This thesis checks the ability of ultrasound scan to image the 3D structure of biofilms nondestructively.

3. The canal anatomy is complex and often long-oval in form (Wu *et al.* 2000). Efficient instrumentation and cleaning of these canals is extremely challenging. It is important to visualize and to have knowledge of internal anatomy relationships before undertaking endodontic therapy. This thesis explores the feasibility of optical coherence tomography as a non destructive method to look at the anatomy of the root canals and associated structures.

The root canal filling

The purpose of filling the root canal is to prevent bacterial growth and penetration of fluid and antigenic agents between the canal and periapical tissues (Sundqvist *et al.*1998). However, current filling materials and techniques fail to provide a leak-free seal (Wu & Wesselink 1993).

A variety of laboratory-based experimental models are used to detect and measure leakage along root fillings. The fluid transport set-up is often used to measure leakage of water through root canal fillings. Xu *et al.* (2005) discussed a new model that measures the leakage of glucose molecules. The glucose leakage model is relatively easy to assemble and use and could give quantitative leakage measurements which are based on an enzymatic chemical reaction between specific enzymes and glucose. This reaction is very sensitive, measured by a spectrophotometer and could detect minute concentration changes of glucose. This thesis uses the glucose penetration model in order to compare the sealing ability of different materials and methods and to further assess the advantages and limitations of this model.

Both mechanical instrumentation and obturation of the root canal walls could introduce defect in the root canal wall (Wilcox *et al.* 1997). These defects could eventually propagate into vertical root fractures and might have clinical significance. The procedures that mostly cause these defects are debatable (Lertchirakarn *et al*. 1999). Evidence exists as to the role of lateral compaction of gutta percha in the formation of vertical root fracture (Dang and Walton 1989), but the ability of other endodontic procedures to cause dentinal defects is not yet fully understood. The new availability of different Ni-Ti rotary files in endodontics could be a contributing factor in the formation of such defects.

Objectives of the thesis

The aim of this thesis was to suggest new methodologies to measure, image and explore the root canal walls and related interfaces and to present new insights into the root canal wall associated with endodontic treatment procedures. Specifically, 3 approaches were taken:

1. Leakage measurements of penetration of glucose through root canal fillings as a new model for assessing the sealing ability of different materials and methods.
2. Novel imaging technologies for non destructive high resolution characterization of the root canal wall and related structures.
3. Studies into the ability of different files and filling methods to inflict defects on the root canal wall.

Outline of the thesis

- In chapter II, the glucose penetration model for leakage tests is tried. Different tests are presented using this model and its ability to detect leakage patterns through different materials, set ups and conditions. Comparison between performance of different materials and methods as observed with this new model and the already established fluid transport model were also made. The limitations of this model to reliably detect leakage through root canal fillings are discussed.
- In chapter III new endodontic applications for novel imaging techniques are suggested. Ultrasound scans to image live biofilms without damaging the delicate 3D structures and vitality of the biofilms, and optical coherence tomography for intra-canal imaging, showing the root canal walls and related structures nondestructively and without using ionized radiation.
- In chapter IV the formation and incidence of dentinal defects in the root canal wall after different preparation and filling procedures are discussed. Comparison is made between the lateral compaction technique and non compaction technique, and between hand files and different rotary Ni-Ti systems.

References:

Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology.(2006) *International Endodontic Journal* **39**, 921-930.

Chavez de Paz LE. (2007) Redefining the persistent infection in root canals: possible role of biofilm communities. Journal of endodontics **33**,652-62.

Dang DA, Walton RE (1989) Vertical root fracture and root distortion: effect of spreader design. *Journal of Endodontics* **15**, 294-301.

Hulsmann M, Peters OA, Dummer PMH (2005) Mechanical preparation of root canals: shaping goals, techniques and means. *Endodontic Topics* **10**, 30-76.

Lertchirakarn V, Palamara JE, Messer HH (1999) Load and strain during lateral condensation and vertical root fracture. *Journal of Endodontics* **25** 99-104.

Şen BH, Wesselink PR, Türkün M (1995) The smear layer: a phenomenon in root canal therapy. *International Endodontic Journal* **28**,141-8.

Sundqvist G, Figdor D, Persson S, Sjögren U (1998) Microbiologic analysis of teeth with failed endodontic treatment and the outcome of conservative re-treatment. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* **85**,86-93.

Svensäter G, Bergenholtz G (2004) Biofilms in endodontic infections. *Endodontic Topics* **9**, 27-36.

Wilcox LR, Roskelley C, Sutton T (1997) The relationship of root canal enlargement to finger spreader induced vertical root fracture. *Journal of Endodontics* **23**, 533-4.

Wu MK, R'oris A, Barkis D, Wesselink PR (2000) Prevalence and extent of long oval canals in the apical third. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* **89**,739-43.Wu MK, Wesselink PR (1993) Endodontic leakage studies reconsidered. Part I. Methodology, applications and relevance. *International endodontic journal* **26**, 203-8.

Wu MK, Shemesh H, Wesselink PR (2009) Limitations of previously published systematic reviews evaluating the outcome of endodontic treatment. *International Endodontic Journal* ***in-print***

Xu Q, Fan MW, Fan B, Cheung GS, Hu HL (2005) A new quantitative method using glucose for analysis of endodontic leakage. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* **99**,107-11.