Different Methods of Studying Root Canal Morphology of Human Tooth: A Review

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Abstract

Successful root canal therapy requires an in-depth knowledge of root canal morphology.False assumptions about the root canal anatomy of teeth may lead to misdiagnosis, missed canals, improper debridement and breakage of root canal instruments during root canal treatment. The objective of this paper was to review the various methods used to study and understand root canal systems. The complexity of root canal morphology presents a challenge to any clinician. Any attempt to perform root canal therapy must be preceded with a thorough understanding of the anatomy of both the pulp chamber and the root canal system.Several methods have been used to examine the root canal system ranging from in vitro methods such as sectioning of teeth, metal castings to advanced in vivo tomographic imaging, along with the use of magnification.

Key words: *pulp chamber, root canal system.*

Introduction

Pulpally involved deciduous and permanent tooth can be preserved by endodontic treatment. The success of root canal therapy is dependent on the clinician's knowledge of root canal morphology, in order to locate all canals and properly clean, shape and obturate the canal space [1-3]. The root canal morphology of teeth is often extremely complex and highly variable.

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A number of factors contribute to the variation found in the root canal morphology which includes the hard tissue surrounding the pulp and also the ethnic background, age and gender of the population studied.

Work done by many researchers has added understanding of the intricacies of root canals. In 1925, Hess reported wide variations and complexity of root canal systems, and Weine in 1969 provided the first clinical classification of more than one canal system in a single root, by using the mesiobuccal root of the maxillary molars as the model. Vertucci developed a classification system, which was more applicable for laboratory studies.

Several studies have examined the macromorphology of root canals in permanent teeth using different methods of analysis[4-6]. These range from decalcification and clearing techniques, ground sections of extracted teeth cast from root canals with celluloid and resin, endodontic access with radiograph and instruments, in vitro radiopaque gel infusion and radiography, macroscopic examination and advanced methods such as computed tomographic techniques [7-11].

Aim of the Article

The aim of the article is to review the various methods used to study and understand the complexities of root canal systems.

Different Methods of Study of Root Canal Morphology

There are different ex-vivo and in-vivo methods to study root canal morphology which range from

decalcification and clearing techniques, ground sections of extracted teeth cast from root canals with celluloid and resin, endodontic access with radiograph and instruments, in vitro radiopaque gel infusion and radiography, macroscopic examination and advanced methods such as computed tomographic techniques.

Decalcification and Clearing Technique

The mechanism of this simple and inexpensive technique renders the surrounding hard tissues transparent through demineralisation after placement of dyes into the root canal system. In 1980, Robertson et al described a simple technique for the in vitro examination of endodontically treated or untreated root canal systems. The technique consists of decalcification with nitric acid, dehydration with alcohol, and clearing with methyl salicylate, which renders the teeth transparent [12].

In another method, proposed by Seelig and Gillis [13] and adapted by Vertucci [14], the dye is injected into the root canals and teeth are cleared, followed by placing in acrylic casting resin. The resultant specimens may be viewed from any direction, rather than merely from the direction they were ground or radiographed. Clearing techniques provide a three dimensional view of the pulp cavity in relation to the exterior tooth surface but it cannot be used in vivo studies.

Sectioning

Sectioning involves longitudinal and cross sectioning of teeth with ultra-thin microtomes with diamond cutting blades, using burs of various sizes and manually grinding with carborundum stones. Weine et. al. [15] sectioned roots of maxillary molars using coarse sand paper disks, thereby exposing the root canal. Greene et. al. [16] vertically sectioned 1300 teeth in order to study their root canal morphology. A high proportion of double canals in single roots was found, especially in the mesiobuccal root of the maxillary molar. With sectioning techniques, the use of burs may alter normal anatomy and the minute curvatures are difficult to follow, regardless of the care exercised in grinding.

Modelling Technique

The modelling technique involves the removal of all surrounding tissues from casts of root canals with woods metal, celluloid or resin [9,17]. Hess first studied the mesiobuccal root of maxillary molars in vitro by forcing latex rubber into pulp cavities [18]. Gomes et al conducted a study to verify if resin models allowed a three dimensional (3D) evaluation of features of pulp morphology of human permanent mandibular incisors, by obturating the patent pulp space with vinyl resin [9]. Plastic casts have also been created to reproduce the root canal anatomy of human mandibular molars. It is a reliable and reproducible technique that provides sufficient details to allow 3D analysis of root canal morphology but it cannot be used in vivo studies.

Radiopaque Contrast Media

Alacam et. al. [19] evaluated the radiopaque properties of different iodine-containing contrast materials mixed with calcium hydroxide powder. Lateral canals are usually not detected on intraoral radiographs, and in some instances can only be observed after obturation with radiopaque material. Neelakantan et. al.[20] compared contrast medium-enhanced digital radiographs with the accuracy of cone beam computed tomography (CBCT), peripheral quantitative computed tomography (pQCT), spiral computed tomography (SCT), plain (plain digi) and contrast medium enhanced digital radiographs (contrast digi), in studying root canal morphology.

They concluded that the CBCT and pQCT were as accurate as the modified canal staining and tooth clearing technique in identifying root canal systems. Clinically, the radiopaque contrast agent is passively injected into the root canal system once sufficient access has been made and appropriate radiographs are taken. With the use of radiopaque contrast medium the images of root canal systems are easier to read and interpret.

Imaging Technique

The discovery of the amazing properties of cathode rays by Professor Wilhelm Konrad Röntgen in 1895, has contributed a great improvement to the dental sciences. Dr. Otto Walkhoff [21] took the first dental radiographs to aid in diagnosis of hard tissue alteration of teeth, to determine location, shape, size and direction of roots and root canals. Radiographs are helpful in estimating the length of canals and also to locate hard to find or disclose supernumerary root canals by examining the position of an instrument within the canal.

Goldman et. al.[22] demonstrated the fallibilities and inherent errors in radiographic interpretation. Radiographs provide a two dimensional view of a three dimensional structure. They are subjected to distortion through improper techniques, anatomic limitations or processing errors.

In addition, the buccolingual dimension is absent on a single film. Several advanced imaging techniques have been developed; some of them related to dental imaging have been discussed here.

Advanced Imaging Techniques

Digital Radiography

In 1970, Mouyen developed radiovisiography. The newer digital systems which rely on electronic detection of an x-ray generated image that is electronically processed and reproduced on a computer screen. Radiovisiography (RVG) is also known as direct digital radiography (DDR). Advantages of this technique include reduced radiation, speed of obtaining the image, enhancement of image, computer storage, transmissibility and a system that does not require chemical processing[23]. This technology offers a multitude of options for improving the visual quality of diagnostic images with appropriate enhancement techniques such as magnification, reverse contrast, pseudo-3D embossing. The drawback is high initial investment costs, also competency in using software may take time to master. Issues related to infection control need to be addressed, as the detectors cannot be autoclaved.

Computed Tomography (CT)

The term 'tomography' was first used to describe sectional radiographic techniques. A tomographic image represents a selected 'layer' or 'slice' of the structure, of which images have been recorded [24]. CT uses x-rays and computers to produce cross sectional slices of the body and has been used in medicine since the early 1970s [25]. Tachibana and Matsumato were the first to suggest the use of tomography to study the root canal system in 1990, but as a result of the poor resolution of conventional medical CT scans they were not able to study the root canals in detail[26]. The advantage of a CT scan is that it allows for 3D reconstruction of root canal systems.

Recently, a new technology known as cone beam computed tomography (CBCT) or digital volume tomography (DVT), which uses an extraoral imaging scanner to produce 3D scans, has become available for dental practice owing to reduced cost and dimensions [20]. This three-dimensional imaging is capable of capturing both skeletal and soft tissues, which can then be displayed together or separately.

Michetti et. al. [27] used CBCT to study the root canal system of human permanent teeth and compared it with histological sections, in order to evaluate root canal systems of mandibular first molars in a Taiwanese population. CBCT is well suited for imaging the craniofacial area. It provides clear images of highly contrast in structures [28]. Still the availability remains limited because of the significant investment required.

Micro CT /Microtomography/High Resolution Tomography

Micro CT has appeared to be an interesting tool for endodontic research because of its improved resolution, which allows a 3D reconstruction of the internal and external morphology of the tooth [29]. In this technique data acquisition is non destructive and allows fast examination of morphological characteristics of a tooth in a detailed and accurate manner[30]. It also has the potential application in preclinical training of students with regard to tooth morphology and endodontic procedures. However, scanning and reconstruction takes considerable time, the equipment is expensive and the technique is not suitable for clinical use.

Spiral Computed Tomography (SCT)

Spiral computed tomography (SCT) has been introduced in endodontics as a diagnostic tool to facilitate access to the internal morphology of soft tissues and hard tissue structures. SCT has been used in the identification of unusual root canal anatomy prior to endodontic therapy. SCT allows faster scanning; thereby decreasing the problem of patient movement during the data acquisition, which has resulted in reduction of problems with image reconstruction and distortion in the final results.

Optical Coherence Tomography (OCT)

Optical coherence tomography (OCT) is a relatively new diagnostic medical imaging technology, which was first introduced in 1991. OCT has evolved into a powerful technique for imaging of transparent and translucent structures. OCT combines the principles of an ultrasound with the imaging performance of a microscope. It creates cross-sectional images of biological structures using differences in the reflection of light. This technique holds promise for full in vivo endodontic imaging[31]. OCT allows placement of an optical fibre into a wet root canal, which is more clinically relevant compared to an endoscope, which requires a dry environment. However, in the current setting, the OCT catheter is expensive. Nonetheless, OCT imaging systems for clinical dental use, are under development.

Tuned Aperture Computed Tomography (TACT)

TACT is a method for achieving three-dimensional information which allows to record images of a desired object and also to isolate a specific area or depth by focusing on information contained within a certain 'slice' thickness. Barton et al conducted a study to detect the second root canal in the mesiobuccal root of maxillary first molars using TACT. TACT shows promise as a supplement to film-based dental radiography and as a digital alternative to conventional tomographic systems used in dento-alveolar applications.

Conclusion

The complexity of root canal morphology presents a challenging objective to endodontists. Recent improvements in digital radiographic imaging systems have introduced many potential benefits to endodontic practice. For most dental practitioners, the use of advanced imaging has been limited because of cost and availability. But, the development and rapid commercialisation of technology dedicated to imaging of the maxillofacial region will undoubtedly increase endodontic treatment success by providing more details about canal morphology.

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