Diagnosis and decision making in endodontics with the use of cone beam computed tomography
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Chapter 1
General Introduction
Introduction

In order to establish a diagnosis the dentist relies on the clinical as well as the radiologic findings. In periapical radiographs that are used in the standard clinician practice, a three dimensional anatomical area is reproduced on two-dimensions. The superimposition of adjacent anatomical structures like the maxillary sinus, the zygomatic arch and the cortical bone are natural burdens for a clear radiographic image. Additionally, the anatomy of teeth is not always clearly visible on periapical radiographs especially in cases of curved or multirooted teeth. These limitations of periapical radiographic images have an impact on the diagnosis and eventually on the treatment plan offered to the patient (1-5).

The cone beam computed tomography (CBCT) has been welcomed in the field of dentistry and particularly in endodontics in the recent years, as it can help the clinician to overcome some of the limitations of periapical radiographs. CBCT scans result to the three-dimensional reconstruction of an anatomical area at a relatively low radiation dose (6-9). Conventional computed tomography scanners for dentomaxillofacial applications have been replaced by CBCT scanners, due to the reduced radiation dose and costs of the latter (6, 10, 11).

There are several dentomaxillofacial CBCT scanners currently on the market, which differ in detector design, scanning and reconstruction parameters (12-16). There are two types of detectors used in CBCT systems: the image intensifier tube/charged coupled detector (IIT/CCD) and the flat panel detector (FPD). The technology of the IIT/CCD is inferior to the FPD, because it introduces artifacts and increased noise levels in the resulting images (17, 18). The scanning parameters include the tube voltage (kVp) and tube current (mA), the scan field of view (FoV) and the positioning of the patient.
The reconstruction parameters include the number of basis projections (acquisitions) used for reconstruction, the voxel size and the reconstruction algorithm. A change in any of these parameters, CBCT hardware and software, results in a different amount of image artifacts and influences the CBCT image quality.

The ability to reduce or eliminate superimposition of the surrounding structures makes CBCT superior to periapical radiographs and it could be a valuable tool in the diagnosis and decision making in endodontics (19). Possible additional applications of the CBCT scans could include the detection of vertical root fractures, the detection of periapical lesions (apical periodontitis) and the estimation of the root canal length.

Vertical Root Fractures

An undetected vertical root fracture can lead to false diagnosis and eventually further treatment that cannot prevent an extensive bone loss. Therefore early diagnosis is important for both the dentist and the patient. There are different radiological and clinical signs related to vertical root fractures, but they are not pathognomonic (20-23). It is known that radiographically a vertical root fracture is visible only if it is on the same plane with the x-ray beam or at an angle of 4° to either side (24).

The only way to be certain of the presence of a vertical root fracture is the direct visualization of it. In endodontically treated teeth suspected of a fracture that can be done either after extraction, or during orthograde retreatment, or endodontic microsurgery. The option of extraction is usually the last treatment option offered by the dentist, and other options are getting priority. In orthograde retreatment after removal of the root canal filling material parts
of the root canal walls are inspected with an operating microscope; factors like the curvature of a root and the level of the root that is fractured can help the fracture to remain undetected. In endodontic microsurgery a fracture can be detected when already the buccal cortical bone is lost and the fractured root surface is uncovered. Furthermore if a vertical root fracture is located on the lingual or palatal part of a root surface it will also be hard to be detected in endodontic microsurgery.

The ability to detect vertical root fractures is clinically compromised and radiographically limited (using only 2-dimensional periapical radiographs). The intuitively perceived advantages of CBCT on this domain have to be explored and analyzed.

**Apical Periodontitis**

It is known that periapical lesions are visible on radiographs when at least a part of the cortical bone is affected, while small lesions or those remaining only on the cancellous bone remain undetected (25-27). Recent studies suggest that CBCT is more sensitive in detecting periapical radiolucencies than radiographs (6, 28, 29). That is attributed to the three dimensional nature of the CBCT, that removes external factors like anatomical noise and poor irradiation geometry that hinder the detection of periapical lesions (28).

The diagnosis of periapical disease and the following treatment options are based on both clinical and radiographic findings. In numerous studies the assessment of the outcome of endodontic (re)treatment is based on the evaluation periapical radiographs (30-41). There are also recent studies based on the evaluation of periapical radiographs and/or CBCT scans that report a discrepancy between CBCT and periapical radiographs with regard to the status of the periapical area (42, 43). That is partly explained by the fact that periapical lesions are three dimensional and the mesio-distal dimension
is not always equal to the bucco-lingual (8, 44). Therefore instead of using the change in one dimension of a lesion as a criterion for the outcome of endodontic (re)treatments, the change of the lesion’s volume could be used. As the reliability of volumetric measurements on CBCT data has been confirmed in in-vitro studies, the use of the volumetric change could be another way of assessing the outcome of endodontic treatments (45-47).

Root Canal Length

The estimation of the root canal length is an important part of the endodontic treatment. Clinicians so far rely mostly on the use of periapical radiographs and electronic apex locators (EALs). Ideally in infected teeth the end point of the root canal filling would be at the apical constriction, the junction between the pulp and the periodontium. The apical constriction is located 0.5-1.0 mm away from the apical foramen for teeth of different ages but the apical foramen can be up to 3mm away from the radiographic apex (48). The combined use of periapical radiographs and electronic apex locators allows for greater accuracy in the root canal length estimation than periapical radiographs only (49,50).

The limitations of periapical radiographs are well known and they are due to the technique sensitivity and subjectivity, as well as on the superimposition of adjacent tissues that increase the danger of errors in the estimation of the root canal length (51-53). The impact of these limitations is more evident in multirotted teeth. On the other hand, measurements obtained from electronic apex locators in partially or totally obliterated root canals are not consistent. Electronic apex locators aim for the area between the apical constriction and the apical foramen (54). Elayouti et al (51) reported a higher frequency of overinstrumentation in posterior teeth in comparison to anterior teeth when periapical radiographs were used. Instrumentation beyond the apical foramen is associated with a poor prognosis and it should be avoided (30, 55).
The ability of CBCT to reduce or eliminate superimposition of the surrounding structures makes it superior to periapical radiographs (57). In that aspect the use of CBCT scans for the root canal length measurement could possibly lead to a more favorable prognosis of endodontic treatments. Recent studies have compared the use of CBCT to EALs for the working length measurement in vivo (57, 58). Although their results support the use of CBCT scans for endodontic working length measurements, a gold standard measurement after extraction of the teeth, did not take place as this was not ethical. Thus the precision of root canal length measurements on CBCT scans and periapical radiographs as compared to a gold standard had to be further investigated. Additionally the influence of tooth type (anterior, posterior) on root canal length measurements had to be examined.
The objectives were:

- To examine whether CBCT scans can be used for the detection of vertical root fractures in endodontically treated teeth.

- To follow the volumetric changes of periapical radiolucencies in endodontically treated teeth one year after orthograde retreatment with the use of CBCT scans.

- To compare the precision of root canal length determination on CBCT scans and periapical radiographs to a gold standard. Additionally to examine the influence of tooth type (anterior, posterior) on root canal length measurements as assessed on CBCT scans and periapical radiographs.
Outline of the thesis

• In chapter 2, the detection of vertical root fractures by CBCT scans is examined. This hypothesis is initially examined in vitro, where artificially created vertical root fractures are tested. In the first study the accuracy of CBCT scans is compared to that of periapical radiographs in vertical root fracture detection, while in the second one, five different CBCT scanners are compared with regard to their accuracy in detecting vertical root fractures. The influence of root canal filling on fracture visibility is examined in both studies. After the encouraging results of the in vitro studies, the validity of two CBCT scanners in detecting vertical root fractures in endodontically treated teeth in vivo was examined.

• In chapter 3, the volumetric changes of periapical lesions of endodontically treated teeth are followed one year after orthograde retreatment. CBCT scans are used to assess the volumetric changes of periapical lesions of mainly multirooted teeth.

• In chapter 4, the precision CBCT scans and of periapical radiographs on root canal length determination is examined. Additionally the influence of tooth type on these measurements is examined.
References


