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Role of CBCT in C-Shaped Canals

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Abstract
C-shaped canal configuration is a root canal modification commonly seen in mandibular second molars. This canal variation can pose a challenge to the clinician during negotiation, debridement and obturation. Knowledge regarding the C-shaped canal configuration is needed to achieve success in endodontic therapy. The development of endodontic therapy has been continuously aided by the application of imaging techniques that permit precise and sensitive examination of anatomical structures. For dentists, the diagnosis with traditional radiography techniques and the management of fillings and debridement are typically challenging. Three dimensional (3D) spatial anatomical navigation is enabled by cone beam computed tomography (CBCT) in 3 volumetric planes (sagittal, axial and coronal) which provides greater accuracy in the identification of C-shaped canal morphologies. This narrative review mentions the theoretical concepts regarding C-shaped canal, Role of CBCT in endodontics, Elements of interpretation and application of CBCT scans in case of C – shaped canal anatomy, limitations in availability, assessment and interpretation of CBCT images.

Keywords: C-shaped Canals, CBCT, Digital Images, Root Canal Treatment

Introduction

In order to succeed in endodontics, one must have a thorough understanding of pulpal anatomy, including its typical and uncommon configurations as well as any potential deviations (Hora et al., 2024). Failure of adequate knowledge could result in treatment failure. In addition to different forms of root canal arrangement and accessory canal morphology a wide variety of developmental tooth, root, and canal anomalies exist, including C-shaped canals, dens invaginatus, taurodontism, root fusion, dilacerations, and palato-gingival grooves. The C-Shaped canal is an important example of such a variation and was first described using this term in 1979 by Cooke and Cox (Yang et al., 2021). The main reason for this anatomical variant, in which a continuous slit or web forms a link between individual root canals, may be the failure of Hertwig's epithelial root sheath to fuse to the buccal or lingual root surface. The development of endodontic therapy has always included the use of imaging techniques that allow for the precise and sensitive examination of anatomical features. Various methods have been devised to observe the morphology of root canals, including cone beam computed tomography (CBCT), magnifying devices, and traditional periapical films (Qian et al., 2022). Among which CBCT, that produces three-dimensional reconstruction pictures, is a useful tool for analyzing the anatomic complexity of the root canal system. The obstacles of conventional radiography are well established. The diagnostic yield of the two-dimensional images is impaired to varying degrees, by anatomical noise masking the area of interest and geometric distortion (Patel et al., 2019).

Role of CBCT in Endodontics

The complexed details of the periodontium and the root canal can only be fully appreciated with extraordinarily high detail and resolution available in cone beam computed tomography imaging utilized in endodontics (Patel et al., 2019). CBCT imaging helps in assessing various features that includes detection of an apical periodontitis.

- Assessing in the outcome of root canal treatment
- Assessment of the root canal and the surrounding anatomical structures and landmarks relevant to the apical surgery
- Dental trauma
- Root resorption
- Vertical-root fractures (VRF)

Obtaining the Image

For generating the 3 dimensional image requires a scanner which needs specific hard ware composed primarily of rotating c-arm gantry that hosts the x-ray source and detector during the scan a beam is directed through the region of interest across the maxillofacial study area. The weakened photons strike the scintillation detector on the opposite side during the reconstruction process each observation unit is assigned a value on a predefined grey scale according to the attenuation of the material on each of its axes x y and z subsequently the values are integrated with the use of mathematical algorithms in specific software which permit volumetric 3 dimensional observations on a computer screen.

Observation Planes

Reconstructed data permits observation in alternative planes oblique planes which are very much helpful in endodontics since it allows for visualization of anatomical structures according to the longitudinal axis of the tooth

Training and Education

Since cone beam computed tomography is still relatively new it has not had much exposure in undergraduate dental education therefore in order for dentists to utilize this novel technique safely and efficiently both newly certified and experienced dentists must become knowledgeable about its uses in accurate diagnosis (Patel et al., 2019). The European academy of dento-maxillofacial radiology (Brown et al., 2014) and public health England in the united kingdom have suggested two levels of training the core course level 1 training is required of individuals who write prescriptions for CBCT scans for individuals who interpret CBCT scans advanced training level 2 is advised.

Digital Workflow

Collect the CBCT data of the patient ensure optimal resolution, appropriate field of view and thickness of the slice

⬇

Open CBCT software (Planmecca Remixes). Load the data of the patients scan.

⬇

Locate the tooth of interest and use thin slices for optimal visualization.

⬇

First select axial view, start examining the axial slices from coronal to apical region.

⬇

In Axial view -examine for C-shaped canal pattern at the orifice level, ribbon-shaped Or fused canal.

⬇

In coronal view – look for the extent of fusion and canal morphology at various levels.

⬇

In sagittal view -confirm the continuity of C-shaped canal pattern.

⬇

Classify the canal based on fans et al classification.

⬇

Look for any complex anatomical feature such as lateral canals, bifurcation and apical complexity.

⬇

Finish the evaluation aspect and continue with clinical planning.

Assessment of Root Canal Anatomy

Strip perforation is a possibility in C-shaped canals because of their thin walls and narrow isthmus. As a result, clinicians struggle to completely comprehend the intricate anatomy of the C-shaped canal. Because of this, clinicians must understand how C-shaped canals are configured and take measures to avoid instrumentation mistakes for successful root canal therapy and in-depth knowledge of the internal structure of root canals, such as the thickness of the canal wall.

Definition and Terminology

The C-shaped root canal was first illustrated by Keith and Knowles. "On the lingual side, the root begins to separate 7 mm below the crown into mesial and distal flangs," they observed, adding that "on the labial aspect, the root shows no trace of division" (Singla et al., 2019). After doing a thorough analysis, Nakayama termed the C-shaped root a "gutter-shaped root". Tratman termed this morphology the 'horse-shoe reduction form'. According to Weine, the C-shaped configuration refers to a continuous slit between all the canals so that a horizontal section through the root yields a space in the shape of a letter 'C'. According to Kato et al., tooth is usually defined as having a C-shaped root canal system when any arbitrary cross section presents a C-shaped root canal configuration (Kato et al., 2014).

Etiology

The primary reason of C-shaped roots, which invariably contain a C-shaped canal, is the inability of the Hertwig's epithelial root sheath to fuse on the lingual or buccal root surface. This fusion failure leaves a coronoapically present groove on the opposite side of the root (Singla et al., 2019). Cementum deposition over time may also lead the roots to consolidate and create C-shaped roots. When the buccal or lingual aspects of the mesial and distal root fuse together, C-shaped canals develop. The interradicular ribbon that connects the roots keeps them together despite the irregularity of this fusion. In C-shaped roots, the lingual surface of the dentin is thinner than the buccal surface. They postulated that a slower rate of dentin production on the labial side is the cause of this C- shaped canal architecture. The researchers were suspicious that the development of a sub pulpal lobe would result in the production of a C-shaped root. Either chromosome 5 / chromosome 17 contain the gene or genes that can lead to C-shaped roots in mice. It's quite likely that one of the potential genes for C-shaped roots in mice is found on chromosome 5 (Kato et al., 2014; Singla et al., 2019).

Classification

This anatomical variation arises from the failure of the Hertwig's epithelial sheath to fuse or develop in the area of the furcation during the developmental stage of the teeth (Bishnoi et al., 2020).

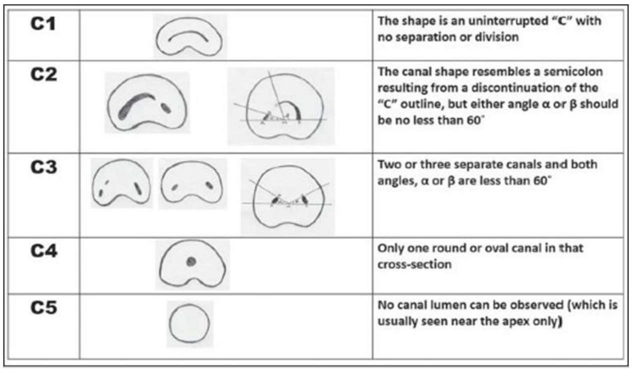

Figure 1 Modified Melton's Method of Classification (Fan et al., 2004)

Incidence and Prevalence

The C-shaped canal is more common among Korean communities than in other populations, with reported prevalence ranging from 31% to 44.5%. In the current study of Koreans, C-shaped canals were found in 36.8% of mandibular second molars. Patients over 51 were less likely than patients in other age groups to have C-shaped root canals, while patients in the 21–30 year age group had a considerably higher prevalence of C-shaped root canals (Yang et al., 2021). Nonetheless, some earlier Korean research indicated that women were far more likely than men to have C-shaped roots (Kim et al., 2016) but refuted by other studies (Jin et al., 2006; Helvacioglu-Yigit & Sinanoglu, 2013). The majority of bilateral C-shaped canals (75.3%) in this study were found to be present in a prior investigation of a Chinese population (Zhang et al., 2011). Consequently, there's a good chance that the contralateral second molar will also have a C-shaped canal if one is found in the mandibular second molar. The Indian population, which is a diverse group that can be traced, has seen relatively few studies in this area. According to a study conducted on the people of North India, the overall prevalence of C-shaped root canals was 6.72% (Wadhwani et al., 2017).

Prior studies have indicated that the C1 type (35.3%) was the most prevalent pattern of C-shaped canals (Zheng et al., 2011). As people aged, the C3b type became more prevalent and the C1 type became less common (Yang et al., 2021). Previous studies have also shown that the existence of a C-shaped morphology in mandibular molar radiographs was predicted by a fused root (Fan et al., 2004; Martins et al., 2016). An earlier study indicated that teeth with thick root canal walls at the orifice region needed special attention since there was a significant drop in thickness towards the apical region with increased root canal wall thickness at the orifice (Seo et al., 2012).

Limitations and Considerations

Although radiation doses from CBCT are generally lower than those from medical CT, caution is advised, particularly in younger patients or those who require numerous scans. Compared to conventional 2D imaging modalities such as periapical radiography, CBCT allows higher radiation doses. The field of view (FOV) might be broad, including several teeth and surrounding structures, or small concentrating on a single tooth. Radiation exposure and the chance of unintentional discovery are both increased by a wider field of view. To balance the need for diagnostics with radiation safety, choosing the right field of view is essential. Small FOVs are advised for diagnosis and treatment in endodontics because they lessen the volume of tissues exposed to radiation and also the ray dispersion, which positively affects the image quality. Generally speaking, the smaller the scanning volume, the higher the spatial resolution of the image, the lower the radiation dose, and the shorter the reconstruction time required. Specific recommendations have also been made based on the particular requirements, even though the majority of authors have recommended narrow FOVs for endodontic applications. Since CBCT equipment is more costly than conventional radiography equipment, some clinics may find it harder to use. Another potential barrier is the expense of CBCT scans for patients. Though CBCT is superior to traditional radiography in terms of resolution for minute details such thin root canals or fissures, it nevertheless produces good three-dimensional images of bone structures. The limited discernibility of smaller structures may curtail its applicability in specific endodontic scenarios. Artifacts (such streaking or noise) might appear in CBCT pictures, particularly if the scan field contains metal restorations or other dental materials. These artifacts can obscure crucial diagnostic data and complicate interpretation. While CBCT is a great tool for seeing hard tissues (tooth and bone), it is not as good at showing details about soft tissues (pulp and periodontal ligament), which are relevant in specific endodontic disorders. When using CBCT to reduce radiation exposure, clinicians must always follow the ALARA (as low as reasonably achievable) principle, which calls for confining the scan to the area of interest and utilizing the lowest feasible radiation dosage. However, not all cases of nonsurgical endodontic treatment can benefit from routine CBCT acquisition. Rather, in endodontics, CBCT must only be utilized when the advantages to the patient outweigh the possible hazards (Yang et al., 2021).

Conclusion

Knowledge of canal configuration enables clinicians to use better treatment techniques, resulting in better outcomes and fewer procedural errors (Fariha Irfan on 25 January 2023). A cone-beam computed tomography (CBCT) scan is always recommended before any endodontic surgery on a mandibular second molar with a C-shaped canal. Appropriate diagnosis, solid understanding of abnormal root canal anatomy, and a comprehensive chemo-mechanical preparation with a three-dimensional obturation of C-shaped canals are necessary for successful endodontic care and to guarantee a favorable long-term prognosis (Bishnoi et al., 2020). It's critical for a dentist to predict the unique anatomy of root canal morphologies. One of these difficulties, the C-shaped canal, is very difficult to detect and treat. Early identification of the C-shaped arrangement makes the root canal system easier to clean, shape, and obturate. In mandibular second molars, the C-shaped root canal morphology is highly prevalent and shows an ethnic predilection (Singla et al., 2019). The anatomical configuration of the C-shaped canal system can vary widely, which makes debridement, obturation, and restoration challenging. These C-shaped arrangements can be recognized with the use of illumination and magnification. When assessing root canal configuration and providing endodontic treatment, the use of CBCT is advantageous. Devices for injectable thermoplasticized gutta-percha and ultrasonic instruments are very helpful for debridement and obturation (Singla et al., 2019).

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