Research progress of mandibular first molar preparation with nickel-titanium instruments under the guidance of CBCT

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Abstract: Endodontic disease or periapical disease is one of the most common oral diseases in clinic. Root canal therapy (RCT) is currently the most common and effective method for the treatment of endodontic or periapical diseases. Root canal therapy (RCT) is currently the most common and effective method for the treatment of endodontic or periapical diseases. The complex root canal morphology of mandibular first molar is a major challenge for its root canal treatment. The application of nickel-titanium instruments has brought new breakthroughs in root canal therapy, but also brought some new hidden dangers. This article reviews the research status of cone beam computed tomography (CBCT) guided nickel-titanium instruments for mandibular first molar preparation in recent years.

Keywords: root canal therapy; the mandibular first molar; nickel-titanium equipment; cone beam computed tomography

Introduction

Mandibular first molars are the earliest permanent teeth that erupt in humans. Due to their special anatomical form, they are prone to caries, and even develop into pulpitis or periapical disease. At present, the treatment of endodontic or periapical diseases of mandibular first molars with nickel-titanium instruments has a significant effect. However, the shape of the root canal after nickel-titanium instrument preparation is often damaged, and the root is prone to complications such as longitudinal fracture. The application of CBCT provides a new diagnosis and treatment idea for root canal therapy. This article sorts out the relevant literatures and summarizes them based on the latest research progress at home and abroad, in order to provide a reference for dentists to choose appropriate nickel-titanium instruments for root canal preparation of mandibular first molars under the guidance of CBCT, and to reduce and prevent complications.

1. Mandibular first molar

1.1 Anatomy of the mandibular first molar

The mandibular first molar has a complex pit and fissure structure on the occlusal surface, which not only makes it play an important role in the chewing process, but also causes a very high caries rate. A survey has shown [1-3] that the caries rate among Chinese adolescents is generally on the rise, among which the first permanent molars are the most serious, accounting for about 1/4. And the lower jaw is significantly higher than the upper jaw, and women are higher than men.

The root morphology of mandibular first molars is most common with mesial and distal double roots. In rare cases, the distal root can be divided into buccal and lingual roots. According to statistics [4, 5], the majority of mandibular first molars have 2 roots (77.4%-96.4%), followed by 3 roots (3.3%-22.2%), and a few cases have 4 roots (0.2%).

Mandibular first molars usually have 3-4 root canals, namely 2 canals in the mesial and 1-2 canals in the distal. In addition, the shape of root canals is often highly variable. Most root canals are not straight, but curved shapes. There are also a large number of lateral root canals. According to the statistics of some scholars [6, 7], it is most common for mandibular first molars to have three root canals, and the incidence is about 55.4%-61.3%. Followed by 4 root canals, about 29.7%-35.7%, and the remaining types were about 1%-14.9%. In addition, the most common root canal types of mesial roots are type IV, accounting for 52.3%-76.8%, followed by type II, accounting for 16.6%-35%, and the remaining types only account for about 6.6%. The root canal types of distal roots are mainly type I, accounting for 62.7%-79.4%, followed by type II, accounting for 6.4%-14.5%, and the remaining types account for 12.4%-14.2%. It can be concluded that the root canal anatomy of mandibular first molars is extremely complex and has many variations. Therefore, it also brings great difficulties to its root canal treatment.

1.2 Danger zone of mandibular first molars

The mandibular first molars have natural weak areas, mainly the isthmus and the danger zone. The isthmus is defined as the pulp channel connecting 2 or more root canals in the same root, so it is also called isthmic anastomosis or isthmus communication. Most mandibular first molars have isthmus, which is mainly located between the buccal and lingual root canals of the mesial root [8]. The existence of the isthmus region is a serious challenge for dentists. Studies have found that the existence of isthmus is one of the main reasons for the failure of root canal treatment of mandibular first molars [9-12]. This may be related to the presence of infectious material in the isthmus region and the difficulty in removal due to the narrow anatomy. The current clinical root canal disinfection mainly uses chemical irrigation and disinfection, including 17% EDTA, 0.5%-5.25% sodium hypochlorite, etc. However, even combined with a dedicated irrigation needle or physical means such as negative pressure irrigation, the debris in the isthmus cannot be completely removed [13]. In addition, the isthmus can also significantly reduce the fracture resistance of the mandibular first molar root, which can be intuitively proved by two-dimensional fracture mechanics analysis of the teeth. For example, Chai et al. [14] showed that the loose connection structure of the isthmus is easily separated by the condensation of gutta-percha or tensile stress generated during occlusion, which in turn promotes the growth of cracks in the root canal wall and eventually causes longitudinal root fractures.

In the past, most scholars believed that the danger zone was located in the distal root canal wall of the mesial root of the mandibular first molar, where the surface was often an elongated depression and the root canal wall was thin [15]. Some studies have found that the danger zone is generally located 4-6 mm below the root canal orifice [16]. Another scholar reported [17] that the minimum distal dentin thickness of the mandibular first molar is located 3-4 mm below the root bifurcation, which further proves that the danger zone is the weakest area in the root, which will significantly reduce the fracture resistance of the root.

However, with the further understanding of the anatomy of mandibular first molars in recent years, scholars have found that the thinnest dentin of the mesial root is not completely located in the distal root canal wall, but also exists in the mesial side of the root. This means that the danger zone may exist in both the mesial and distal sides [18]. Therefore, if you do not pay attention to the danger zone of the root during root canal treatment of mandibular first molars, the risk of root band perforation and longitudinal root fracture may occur.

2. nickel-titanium Instruments

The emergence of nickel-titanium instruments has brought rapid progress in root canal treatment, especially for teeth with complex root canal shapes such as mandibular first molars. A deeper and more comprehensive understanding of nickel-titanium instruments is essential.

2.1 Rotation method of nickel-titanium instruments

With the rapid development of emerging technologies, nickel-titanium instruments are widely used in endodontics, which has revolutionized root canal preparation, enabling more complex root canal systems to be effectively prepared [19]. At present, the commonly used nickel-titanium instruments on the market can be divided into manual nickel-titanium instruments, continuous rotary nickel-titanium instruments and reciprocating nickel-titanium instruments [20-22]. Manual nickel-titanium instruments are used in a similar way to traditional stainless steel instruments, but with greater flexibility. Continuously rotating nickel-titanium instruments use the same-direction and continuous rotation movement mode, and the cutting efficiency is higher. The movement mode of reciprocating nickel-titanium instruments is 4/10 clockwise rotation and 2/10 counterclockwise rotation, which can effectively reduce the incidence of instrument breakage [23].

2.2 Advantages of NiTi instruments

Compared with traditional stainless steel devices, nickel-titanium devices have distinct advantages, including superelasticity, flexibility, fatigue resistance, and shape memory [24-26]. The flexibility and fracture resistance of NiTi instruments are 2-3 times higher than those of stainless steel files [27], which makes them more efficient and safer [28]. Another study found that [29], nickel-titanium instruments are less prone to apical deviation than stainless steel instruments, which allows the apical segment to be filled more tightly and improves the success rate of root canal treatment. To sum up, nickel-titanium instruments have the advantages that traditional stainless steel instruments are difficult to replace in various aspects.

2.3 Disadvantages and clinical risks of nickel-titanium devices

2.3.1 Instrument separation

Nitinol devices are prone to device separation due to various factors such as excessive torsion and metal fatigue [30-32]. Kim et al. [33] conducted fatigue tests on NiTi devices, and the results showed that when NiTi devices were cycled to 75% of their fatigue life, their torsional resistance was significantly reduced. For the two mechanistic nitinol systems that are more commonly used in clinical practice, reciprocating nitinol instruments have higher cyclic fatigue and torsional resistance than continuous rotary ones [34]. Not only that, but the design of NiTi instruments, including cross-sectional geometry, blade design, and surface treatment, all play a crucial role in cyclic fatigue [35]. In addition, Sattapan et al. [36] found that excessive use of apical force during root canal preparation can also lead to fatigue of nickel-titanium instruments.

2.3.2 Root fracture caused by dentin microcracks

The powerful cutting ability of NiTi instruments can effectively remove the infected tissue in the inner wall of the root canal, but it also increases the risk of root fracture. Dentin microcracks are a kind of tissue defect existing in the root dentin, which can not only reach the dentin layer through the inner wall of the root canal, but also penetrate the root dentin to connect the inner wall of the root canal and the outer wall of the root. Dentin microcracks may naturally exist in normal roots, mainly in the cervical 1/3 and middle 1/3 of the root, and after endodontic treatment, dentin microcracks may develop into longitudinal root fractures [37]. Although Cavalcante et al [38] found no causal relationship between the number of dentin microcracks and the fracture resistance of mandibular incisors without endodontic treatment. And the presence and number of dentin microcracks does not make these roots more prone to fracture, but the current view that dentin microcracks are one of the main causes of longitudinal root fractures is still the mainstream.

In addition to congenital microcracks, nickel-titanium device preparation can also lead to the development of microcracks. Root canal preparation can lead to apical microcrack formation regardless of the type of nickel-titanium rotary instrument [39]. However, the reciprocating nitinol instruments produced fewer dentin microcracks than the continuously rotating nitinol instruments [40], which may be related to the different stress caused by different movement patterns. This was also demonstrated by Shantiaee et al. [41], who also found that the single-file system formed more dentin microcracks in the apical third than the multi-file system.

2.3.3 Root fracture caused by excessive cutting of NiTi instruments

Longitudinal root fracture is not only related to dentin microcracks. The weakening of remaining dentin caused by excessive cutting of nickel-titanium instruments is also one of the important reasons. Mandibular first molars have natural danger zone in the root due to their flat and thin root morphology. Once these areas are cut too much, the remaining dentin thickness of the root is too small to withstand the strong occlusal force and cause fracture. Keles et al [42] showed that the fracture resistance of the mesial roots of mandibular first molars was reduced after preparation with large-taper nickel-titanium instruments. In a subsequent study, they evaluated the residual dentin thickness after each root canal preparation in the mesial root of mandibular first molars and found that the wall thickness was significantly reduced at each scan level. And it is believed that the preparation of the mesial root of mandibular molars should preferably use instruments with small taper [43]. Since the mesial root of mandibular first molars is a common site for longitudinal root fractures, the dentin of the root canal wall should be preserved as much as possible when using nickel-titanium instruments to prepare the mesial root. However, the specific thickness of dentin that should be preserved has been studied by many scholars, but the results of the studies are not the same [44-46], so more in-depth studies with increased sample size are still required. All in all, in order to avoid the occurrence of complications such as longitudinal root fracture, it is necessary to preserve the dentin to the maximum extent, and it is particularly important to select the appropriate type of nickel-titanium instrument.

3. The application of CBCT in root canal therapy

Nickel-titanium instruments have greatly optimized the treatment process of root canal, and good treatment is inseparable from accurate diagnosis and determination of treatment direction. CBCT is the guiding light in root canal treatment.

X-ray examination is the most commonly used imaging examination method in stomatology, but it has certain limitations in the diagnosis of certain diseases due to its shortcomings such as image overlap, artifact and image deformation caused by two-dimensional images. The emergence of CBCT has greatly improved the diagnostic success rate of difficult oral cases and promoted the development of oral medicine. Compared with spiral CT, CBCT has the advantages of small voxel, high image spatial resolution, short scanning time, and low radiation dose, so it is widely used in clinical practice [47-51].

At present, CBCT is mainly used to assist in finding missing root canals, apical cysts, longitudinal root fractures and other difficult cases that are difficult to accurately judge by two-dimensional images in endodontic diseases. However, it is rarely used for the evaluation of root anatomy and complex root canal system, which inevitably leads to underestimation or even misestimation of the number and anatomical shape of its variation, resulting in a decline in the quality of root canal preparation, and ultimately leading to poor long-term treatment effects. Mandibular first molars not only have flat and thin root morphology, but also have a large degree of variation in root canal morphology. Therefore, the advantages of CBCT can be fully utilized to measure the root dentin thickness of mandibular first molars, and to pre-analyze whether there are other anatomical weak areas in addition to the known danger zone, so as to select appropriate preparation instruments. Shaikh et al [52] measured the dentin thickness and volume of maxillary central incisors before and after root canal preparation, and believed that CBCT was a reliable linear measurement of tooth dentin thickness. Xu et al[53] also believed that CBCT imaging can accurately measure dentin thickness after measuring mandibular molars using CBCT. Furthermore, the use of CBCT images to predict residual dentin thickness after simulated instrument removal is also reliable and feasible.

4. Conclusion

The complex root canal shape of the mandibular first molar is a difficult problem in endodontic treatment. Traditional stainless steel instruments cannot solve this problem well. The emergence of nickel-titanium instruments has brought new solutions to it. Nickel-titanium instruments have many advantages such as superelasticity, flexibility, fatigue resistance and shape memory ability, but they also have their own defects that cause certain clinical risks, such as instrument separation, longitudinal root fracture, etc. CBCT provides a new guiding idea for root canal treatment of mandibular first molars by measuring the root canal wall and simulating the effect of root canal preparation.

5. Prospects

At present, the research on mandibular first molars at home and abroad mostly focuses on the measurement and analysis of the minimum dentin thickness and distribution area in the danger zone distal to the mesial root. In addition, whether the existence of the isthmus also affects the distribution of the minimum dentin thickness in the danger zone has important clinical significance and deserves further in-depth study.

Currently, the methods used to measure dentin thickness mainly include serial section, Micro-CT and CBCT measurement. Serial sectioning can only be performed on in vitro specimens because of its destructiveness, and

Micro-CT can only be performed in in vitro specimens or animals due to its volume, while CBCT has high-quality imaging and can be acquired clinically. Its accuracy in measuring dentin thickness was also not significantly different from Micro-CT [54]. In addition, CBCT can also be used to simulate the preparation of nickel-titanium instruments and to measure the thickness of the root canal wall after preparation, to analyze the danger zone of each root, and to guide the selection of suitable nickel-titanium instruments. CBCT should receive more attention and application, so that CBCT can play a better role in endodontic root canal treatment. Before complex root canal treatment, CBCT enables dentists to have a clearer and more comprehensive understanding of the root canal shape, so that a more accurate diagnosis can be made. Combined with the use of high-quality equipment, the ideal treatment results can be finally obtained, the treatment risks can be avoided, and the patients can achieve excellent outcomes to the greatest extent.

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