REVIEW ARTICLE

Management of third molar teeth from an endodontic perspective

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ABSTRACT

Third molar teeth are subject to many dental complications because of their most posterior location, aberrant occlusal anatomy and abnormal eruption patterns. Owing to these anatomical limitations, their extraction remains the treatment of choice for many dental practitioners. Despite being a common dental procedure, minimum intervention and retaining every functional component of the dental arch are of prime importance in contemporary dental practice. As such, this review aims to discuss the application of this conservative approach on third molar teeth from an endodontic perspective. The internal and external root anatomy of maxillary and mandibular third molars and their relation to the surrounding vital structures are described. These anatomical landmarks are then correlated to the decision making for endodontic treatment strategies of third molars. In addition, the recommended guidelines that should be followed while commencing endodontic treatment in third molars are outlined.

Key words
Autotransplantation, endodontic treatment, root, root canal, pulpotomy, third molars

INTRODUCTION

Despite the educational efforts and oral hygiene programs organized by many dental associations to improve the oral and dental health, third molar teeth always are prone to dental decay due to their most posterior location and wrinkled occlusal anatomy that would favor plaque accumulation and obscure the proper access to the tooth surface for optimum cleaning.[1] Apart from that, they usually appear in the oral cavity with abnormal eruption patterns, which also make them more susceptible to dental decay, as well as gingival and periodontal diseases.[1] Owing to these detrimental complications, extraction of third molar teeth usually is considered as a common dental procedure.[1,2]

Minimum intervention and retaining every functional component of the dental arch, including third molars, are the principle goals of contemporary dental practice.[3-6] In some clinical situations, the retention of a third molar would be essential if the tooth is functional and/or would serve as a convenient abutment for future fixed or removable prosthetic restoration. As such, third molar teeth scheduled for endodontic therapy should be treated thoroughly to ensure the complete elimination of the inflamed dental pulp and microbial irritants from the root canal system that, if left, would impair the clinical outcomes of the proposed treatment plan.

Before commencing endodontic treatment in third molar teeth, a meticulous understanding of their root and root canal anatomical variations and their endodontic implications is of prime importance. In this article, the external and internal radicular anatomical variations reported in previous laboratory and clinical investigations are discussed. In addition, the treatment strategies and recommended guidelines that should be followed during endodontic treatment of third molars are described.

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ROOT AND ROOT CANAL MORPHOLOGY

A comprehensive review on the literature was undertaken in PubMed and Google Scholar search engines from year 1972 to 2012, to identify relevant and available laboratory studies, clinical investigations and reported cases that demonstrated the normal and unusual external and internal radicular morphological features of maxillary and mandibular third molar teeth. The results show that the root and root canal morphology of third molars show an increased likelihood for root and root

canal aberrations, either in number or shape [Figure 1]. Tables 1-3 summarize these anatomical variations.

Variation in number of roots/root canals

Maxillary third molar teeth

Maxillary third molars show considerable variations in size, contour and relative position to other teeth.[7] The number of roots in maxillary third molar teeth ranges from one to five[8] [Table 1 and Figure 1], and the number of encased root canals have been reported from one to six [Table 1]. However, the single, double and three-rooted variants, either separate or fused, encasing one to four root canals are considered the most common[4,9-15] [Table 1].

The internal anatomy of the mesiobuccal root in three-rooted maxillary first molars has been investigated more than any other root.[16,17] However, few studies examined the occurrence of second mesiobuccal canals in third molar teeth. Green[18] found that the prevalence of a second canal in the mesiobuccal root of maxillary third molars was 37% in which 25% of the Mb2 were type II (2-1) and 12% were type IV (2-2). In an *in vitro* investigation on 50 maxillary third molars, Pécora *et al.*[15] found that 68% of Mb2 canals have root canal type I (1-1), while root canals types IV (2-2) and V (2-1) were only presented in 14% and 18%, respectively. In 1999, Stropko[19] evaluated the endodontic treatment of 20 third molar teeth, and found only 20% of the study subjects having a second mesiobuccal canal in which all of them where joined and ended in a single foramen.

The internal anatomy of the mesiobuccal root in maxillary third molars has also been examined in some population groups. In a Burmese population, Ng *et al.*[11] reported 22.2%, 11.1% and 5.6% of the mesiobuccal root in maxillary third molars having root canals types IV (2-2), II (2-1), VII (2-1-2), respectively. Apart from that and in a Thai population, Alavi *et al.*[12] demonstrated single canal type I (1-1) in the mesiobuccal root in only 54.5%, and seven different root canal configurations, including type (3-2), were identified in 45.5% of the specimens. In a recent morphological study on a Turkish population by Sert *et al.*[10] 22.22% of the root canal configurations in the mesiobuccal root were types II (2-1), IV (2-2) and V (1-2).

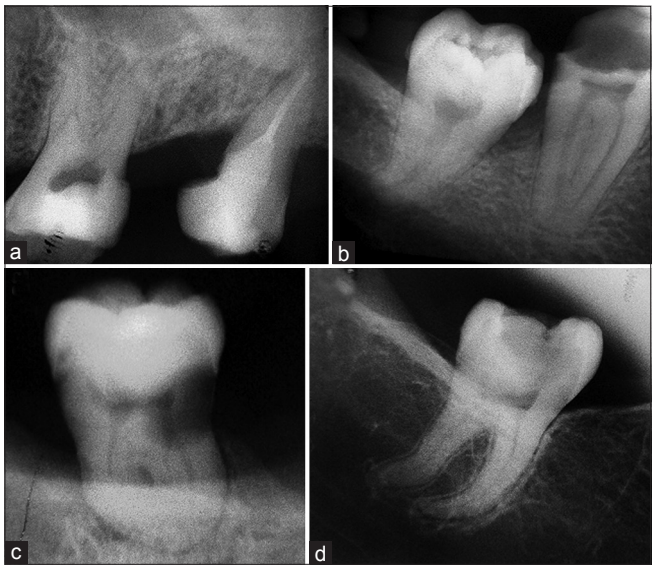

Figure 1: Morphological variations of third molar teeth. (a) Single rooted maxillary third molar. (b) Single rooted mandibular third molar. (c) Mandibular third molar with fused roots. (d) Mandibular third molar with a severely curved root

Despite the considerable morphological variations reported in the mesiobuccal root among different studies, the internal anatomy of the distobuccal and palatal roots in three-rooted maxillary third molars usually is presented as a single root canal type I.[10-12,19]

Lateral canals in the coronal, middle and more commonly in the apical third of the root have been reported in 0.3-4%, 3.7-5% and 9.3-15% of maxillary third molar teeth, respectively.[11,12]

The length of human permanent molar teeth usually decreases from the first to third molars. The length of maxillary third molar teeth ranges from 14 to 22 mm with an average of 17-19 mm.[7,9,20,21] This length would favor the use of short endodontic files (21 mm) thus facilitating the mechanical instrumentation procedure in such teeth with restricted accessibility.

Mandibular third molar teeth

The morphological features and position of mandibular third molars always are unpredictable, and vary among different individuals.[22] Mandibular third molars may have one to four roots, and similar to maxillary third molars, the number of encased root canals has been reported between one and six [Table 2]. However, the single and double-rooted variants encasing two or three root canals are considered the most common.[4,10,13,23-25]

In double-rooted mandibular third molars, >90% of the root canal configurations in the mesial root are presented in four types I (1), II (2-1), IV (2-2) and V (1-2), where type I and II are the most common.[10,18,23-25] Interestingly, Sert *et al.*[10] have reported a new root canal configuration type (2-5-1) in a mesial root of a mandibular third molar. While the root canal configuration in the distal root is type I in more than 90%,[10,23-25] other root canal configuration types II (2-1), IV (2-2) and V (1-2) have also been reported.[10,23,25]

In single-rooted mandibular molars, the mesial root canal has been reported with configuration types I, II, IV and V, while the distal root canal is type I.[10,23] Interestingly, Nimigean *et al.*[6] presented an endodontic management of a single-rooted third mandibular molar with a rare root canal configuration type III (1-2-1).

Lateral canals in the coronal, middle and more commonly

Table 1: Summary of number/percentage of roots and root canals in maxillary third molar teeth

Author/s	Year	Type of study	Root (NI)	1 root	2 roots	3 roots	4 roots	5 roots
Pineda and Kuttler[25]	1972	*In vitro* Radiographic (n=292)	1C=21.4% 2C=51.7% 3C=21% 4C=5.9%					
Green[18]	1973	*In vitro* (Mb root) Vertical ground sections (n=100)		1C=63% 2C=37%				
Pécora *et al.*[15]	1992	*In vitro* (Mb root) Clearing (n=50)		1C=68% 2C=32%				
Guerisoli *et al.*[9]	1998	*In vitro* Clearing (n=155)		1C=7/155 2C=12/155	2C=3/155	3 sep 3C=35/155 4C=5/155 2 fused/1sep 2C=3/155 3C=37/155 4C=9/155 3 fused 3C=33/155 4C=5/155	4C=3/155 5C=2/155	5C =1/155
Stropko[19]	1999	*In vivo* (n=25)	2C=5/25 3C=15/25 4C=5/25					
Sidow *et al.*[4]	2000	*In vitro* Clearing (n=150)		1C=4/150 2C=4/150 3C=9/150 4C=3/150 5C=2/150 6C=1/150	3C=33/150 4C=7/150 5C=1/150	2C=1/150 3C=44/150 4C=22/150 5C=1/150	4C=9/150 5C=2/150	
Ng *et al.*[11]	2001	*In vitro* Clearing (n=72)		1C=2/72 2C=9/72 3C=3/72	2 fused 1C=2/72 2C=8/72 3C=4/72	3 sep 3C=11/72 4C=7/72 3 fused 2C=1/72 3C=15/72 4C=6/72	4 fused 3C=1/72 4C=3/72	
Alavi *et al.*[12]	2002	*In vitro* Clearing (n=151)		1C=2/151	2 fused 1C=2/151 2C=8/151	3 sep 3C=45/151 4C=31/151 5C=1/151 2 fused/1sep 2C=1/151 3C=12/151 4C=2/151 5C=1/151 3 fused 1C=11/151 2C=8/151 3C=17/151 4C=4/151	4C=3/151	
Čosić *et al.*[13]	2008	*In vitro* (n=56)	1C=7.1% 2C=7.1% 3C=75% 4C=10.7%	8.9%	5.4%	83.9%	1.8%	
Sert *et al.*[10]	2011	*In vitro* Clearing (n=290)		1C=36/290 2C=40/290 3C=26/290 4C=1/290	(n=83) Buccal root 1C=38/290 2C=41/290 3C=4/290 Palatal root 1C=82/290 2C=1/290	3C=77/290 4C=22/290	4C=5/290	

NI - Not identified; Mb - Mesiobuccal; Sep - Separate; C - Root canal; C-shaped canals are excluded; Separate canals - Separate orifices or one canal dividing into separate canals

Table 2: Summary of number/percentage of roots and root canals in mandibular third molar teeth

Author/s	Year	Type of study	1 root	2 roots	3 roots	4 roots
Pineda and Kuttler[25]	1972	*In vitro* Radiographic (n=259)		1C(M)=65.8% 1C (D)=92.2% 2C(M)=34.2% 2C(D)=7.8%		
Green[18]	1973	*In vitro* Vertical ground sections (MR) (n=100)	1C=74% 2C=26%			
Guerisoli *et al.*[9]	1998	*In vitro* Clearing (n=114)	1C=14/114 2C=42/114 3C=3/114	2C=37/114 3C=16/114	3C=2/114	
Sidow *et al.*[4]	2000	*In vitro* Clearing (n=150)	1C=5/150 2C=10/150 3C=7/150	2C=15/150 3C=70/150 4C=23/150 5C=3/150 6C=1/50	3C=6/150 4C=1/150 5C=1/150	4C=1/150 5C=1/150
Gulabivala *et al.*[23]	2001	*In vitro* Clearing (n=58)		2 separate Rs 1C(M)=15/58 2C(M)=16/58 1C(D)=31/58 2 fused Rs 1C=1/58 2C=15/58 3C=10/58 4C=1/58		
Gulabivala *et al.*[24]	2002	*In vitro* Clearing (n=173)	2C=1/173	2 separate Rs 1C(M)=71/173 2C(M)=46/173 1C(D)=110/173 2C(D)=7/173 2 fused Rs 1C=8/173 2C=17/173 3C=7/173 4C=1/173	2C(M)=2/173 1C(D)=2/173 1C(DL)=2/173	3C=1/173
Plotino[3]	2008	Case report				4C
Čosić *et al.*[13]	2008	*In vitro* (n=50)	56%	44%		
Sert *et al.*[10]	2011	*In vitro* Clearing (n=370)	1C=40/370 2C=44/370 3C=8/370	(n=257) 1C(M)=151/370 2C(M)=106/370 1C(D)=255/370 2C(D)=2/370	3C=14/370 4C=5/370 5C=1/370	4C=1/370

M - Mesial; D - Distal; MR - Mesial root; C - Root canal; C-shaped canals are excluded; Separate canals - Separate orifices or one canal dividing into separate canals

in the apical third of the root have been reported in 0.3-3.4%, 0.7-5.6% and 4.1-14.6% of mandibular third molar teeth, respectively.[23,24]

Similar to maxillary molars, the length of mandibular molars decreases from the first to third molars. The length of mandibular third molars ranges from 16 to 20 mm with an average of 18-19 mm,[9,20-22] which also would facilitate the mechanical instrumentation procedure using short endodontic files.

Variation in shape of roots/root canals

Dilaceration

The definition of root dilaceration varies in the literature.[26] Nevertheless, many authors define root dilaceration as a deviation or bend of 90-degree angle or greater along the axis of the tooth or root.[27-30] Few studies examined this anatomical variation in third molar teeth among different population groups, as shown in Table 3, and the prevalence has been found to be relatively higher in mandibular third molars, ranging from 3.3 to 30.92%, compared to maxillary molars that ranges from 1.33 to 8.46% [Table 3]. Mechanical trauma is the most commonly accepted cause for root dilacerations. However, the increased prevalence of root dilacerations in molar teeth, which are less prone to mechanical trauma, brought other aetiological factors into consideration. These factors include idiopathic developmental disturbances, hereditary factors and the effect of related anatomical structures, such as the cortical bone of maxillary sinus and the mandibular canal.[26]

Root dilacerations in third molars can occur anywhere along the length of the root from the coronal third to the

Table 3: Summary of radicular abnormalities reported in third maxillary and mandibular molar teeth

Author/s	Year	Type of report	Reported anatomy
Hemmig[39]	1979	Case report	Extraction of mandibular 3rd M fused with distomolar
Goldberg *et al.*[38]	1985	Case report	Endodontic management of mandibular 3rd M fused with 2nd M
Hou and Tsai[33]	1989	Case report	Extraction of maxillary 3rd M fused with a distomolar
Rotstein *et al.*[34]	1997	Case report	Endodontic management of mandibular 3rd M fused with 2nd M
Turell and Zmener[35]	1999	Case report	Endodontic management of mandibular 3rd M (left) fused with a distomolar
Turell and Zmener[36]	1999	Case report	Endodontic management of mandibular 3rd M (right) fused with a distomolar
Sidow *et al.*[4]	2000	*In vitro* (Clearing method)	Maxillary 3rd M: C-shaped canals in 2R= 7/150 Mandibular 3rd M: C-shaped canals in 1R= 3/150 C-shaped canals in 2R= 3/150
Gulabivala *et al.*[23]	2002	*In vitro* (Clearing method)	C-shaped canals in 1-rooted mandibular 3rd M: 1C= 5/173 2C= 9/173 3C= 4/173 4C= 1/173
Hamasha *et al.*[27]	2002	*In vivo* (Periapical radiograph) (Jordanian)	Maxillary 3rd M: Dilaceration: 4/301 (1.33%) Mandibular 3rd M: Dilaceration 63/328 (19.21%)
Kannan *et al.*[31]	2002	Case report	Dilacerated roots in four-rooted maxillary 3rd M
Malčić *et al.*[28]	2006	*In vivo* (Periapical/panoramic) (Croatian)	Maxillary 3rd M: Dilaceration: Periapical= 7/86 (8.1%) Panoramic= 45/532 (8.46%) Mandibular 3rd M: Dilaceration: Periapical= 19/79 (24.1%) Panoramic= 179/579 (30.92%)
Udoye and Jafarzadeh[29]	2009	*In vivo* (Periapical radiograph) (Nigerian)	Maxillary 3rd M: Dilaceration: 3/82 (3.7%) Mandibular 3rd M: Dilaceration: 2/60 (3.3%)
Zeylabi *et al.*[37]	2010	Case report	Endodontic management of a mandibular 3rd M fused with a distomolar
Miloglu *et al.*[30]	2010	*In vivo* (Periapical radiograph) (Turkish)	Maxillary 3rd M: Dilaceration: 30/404 (7.4%) Mandibular 3rd M: Dilaceration: 39/305 (12.8%)

M – Molar; R – Rooted

root apex, and may include a single or all roots[26,28,31] They usually are located in a distal direction. However, buccal dilacerations have also been reported in maxillary and mandibular third molars.[28,31] Root dilacerations may also occur in more than one plane such as in a disto-lingual direction. Recognizing the direction of the file while determining the working length of the encased root canal might be helpful in identifying such complex radicular morphology [Figure 2].

C-shaped canals

Few experimental studies demonstrated the prevalence of C-shaped canals in third molar teeth [Table 3]. Sidow *et al.*[4] reported the presence of C-shaped canals in 4% of mandibular third molar teeth (2% in single and 2% in double-rooted), whereas 4.67% were identified in maxillary third molars (all of them were double-rooted). In another laboratory investigation on a Thai population, Gulabivala *et al.*[23] found 10.9% of single rooted mandibular third molars having C-shaped variants. Apart from experimental studies, the literature also shows successful endodontic management of maxillary and mandibular third molars with C-shaped canals.[5,32]

Fusion

Fusion of teeth is a developmental malformation that refers to the union of two normal tooth germs, or a normal with a supernumerary tooth germ. Although this developmental anomaly usually is reported in the deciduous dentition, some articles reported its occurrence in permanent mandibular as well as maxillary third molars[33-40] [Table 3]. Fusion of molar teeth shows a high predisposition for caries and periodontal disease.[37] Despite the complex root canal anatomy and tooth positioning in such cases, successful endodontic treatment has been reported in third molars fused with either second molars,[34,38] or distomolar teeth.[35-37] Owing to the usual existence of a common pulp chamber in the

fused molar teeth, a modification of the access cavity configuration, usually wider in a mesio-distal dimension, is required to locate all the root canal orifices.

Endodontic treatment strategies for third molar teeth

I) Conventional endodontic treatment

Before commencing endodontic treatment to third molar teeth, an accurate clinical and radiographic assessment should be carried out.

Clinical examination

During clinical examination, the dental practitioner should identify:

- The extension of decay and possibility for restoration
- Mouth opening and accessibility
- Future involvement as a functional component in a proposed treatment plan [Figure 3]. For instance, third molars having dilacerated roots might be a risk factor for stress concentrations and displacements if selected as an abutment in a fixed prosthesis.[41]

While it seems sensible to retain every third molar whenever the opposing is present and in function, it is also preferable to retain third molars even when the opposing is absent in the following clinical situations:

1. The adjacent second molar tooth is missing or badly decayed with poor prognosis [Figure 3a-e], and the third molar is a good candidate for fixed prosthodontic treatment
2. An isolated loss of the permanent first molar is a common problem. In some selected cases, an orthodontic translation of the second and third molars to close the edentulous area may provide a viable and more conservative treatment option than the fixed prosthodontic approach.[42] It is worth noting that endodontically treated teeth can be moved orthodontically similar to vital teeth with no predisposition to root resorption[43] [Figure 3f]
3. When there are multiple edentulous areas and the third molar would act as a strategic abutment for a bounded saddle removable partial denture. This would serve as a more predictable treatment option rather than extraction and complicating the case to a free end saddle with reduced bone height [Figure 3g].

Radiographic examination

In spite of the two-dimensional images provided by conventional radiographic examination, a properly exposed and processed periapical radiograph would provide adequate knowledge on the external and internal anatomical landmarks of third molar teeth and the surrounding anatomical structures. Although digital radiography offers real-time image display, reduced radiation exposure and ease of archiving,[44] the use of some relatively thick sensors would increase

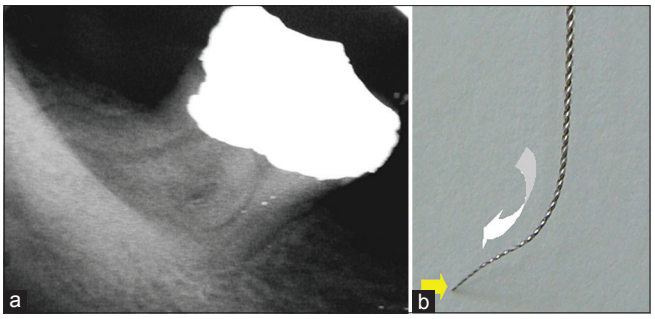

Figure 2: (a) Mandibular third molar with dilacerated mesial and distal roots. (b) A K-file size 10 shows an apparent disto-lingual curvature of the mesio-lingual root canal. This may indicate a disto-lingual dilaceration of the mesial root

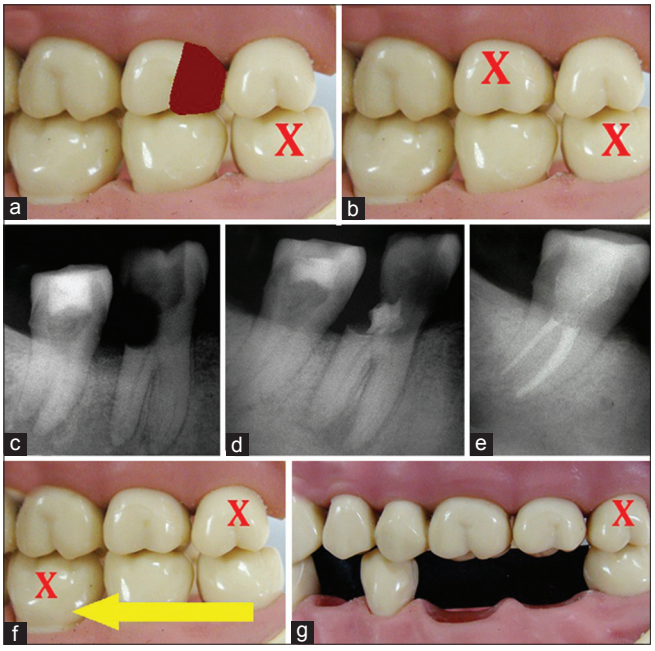

Figure 3: Indications for retaining 3rd molar teeth, even when the opposing is missing (Red cross). (a,b) Badly decayed or missed 2nd molar, and the 3rd molar is good candidate for fixed prosthesis. (c-e) An exposed mandibular 3rd molar was scheduled for endodontic treatment due to the presence of badly decayed 2nd mandibular tooth, which was fractured due to biting on a hard object. The 2nd molar was extracted and the 3rd molar was retained as an abutment for a removal partial denture. (f) Orthodontic treatment. (g) Removable partial denture

the probability for a gag reflex. Cone beam computed tomography (CBCT) provides three-dimensional imaging with low radiation dose and reasonably high resolution that would aid in identifying the root and root canal morphological features similar to modified canal staining and clearing techniques.[45] However, CBCT should only be considered when the conventional periapical radiographs fail to provide adequate information about the area of interest, as CBCT views may also show some misleading findings.[46]

Management of the gag reflex

Sometimes, a gag reflex, caused by stimulating the

posterior dorsum of the tongue or the soft palate, is induced while performing intraoral radiographic examination of third molar teeth, which may get worse during rubber dam placement.

The following guidelines are recommended to control this condition:

1. Patient apprehension should be reduced. This would help the patient to follow the instructions
2. The tongue should be relaxed by asking the patient to swallow before opening the mouth for film placement. In addition, the patient is advised to breathe through the nose because mouth breathing usually aggravates the gag reflex[47]
3. During film placement, it should be positioned into the mouth parallel to the occlusal plane, and when the third molar area is reached, the film is rotated into contact with the palate or the floor of the mouth[47]
4. If the previous attempt did not work with maxillary third molars, the film can be placed flat in the mouth (in the occlusal plane) so it does not touch the palate and the image is taken by applying the principle of bisecting angle technique[48]
5. In extreme cases, topical anesthetic agents in mouth washes, spray or lozenges can be administrated to produce temporary numbness to the tongue and palate to reduce gagging[47,48]
6. The rubber dam is generally tolerated by patients as it is usually away from the areas where the reflex is triggered. However, during commencing endodontic treatment in third molars, the rubber dam becomes near to those areas, and the operator should be cautious during placement to keep away as much as possible. The electronic apex locator would minimize the need for additional exposures.

Radiographic interpretation

The dental practitioner should be able to interpret the following:

Root and root canal morphology

The external and internal morphological features of third molars scheduled for endodontic treatment should be identified accurately. Two periodontal ligament spaces on one side of a root or crossing of periodontal ligament space over the root usually indicate the existence of an accessory root.[8] Root dilacerations and fusion with other teeth can be detected easily. The appearance of a break point or abrupt diminishing in the root canal indicates the presence of a root canal bifurcation.

Relation to surrounding vital structures

Following radiographic interpretation of the root and root canal morphology, the relation of third molars to the surrounding anatomical structures should be identified. The close relation between the roots of maxillary molars and the floor of maxillary sinus are more commonly reported in first and second molars than third ones.[49] However, with extensive pneumatization, especially when the second molar is missing, the roots of maxillary third molars may become exposed into the sinus. This close relation can be identified accurately with the aid of three-dimensional imaging such as CBCT.[50] The accurate perception and consideration of this close relation would avoid the occurrence of some serious complications such as sinus inflammation or perforation due to over-instrumentation, broken files and extrusion of endodontic materials such as irrigants, intracanal medicaments or root canal filling materials.[49,51] It is also worth noting that third molars having roots in the maxillary sinus and scheduled for autotransplantation would require special manipulation to ensure an appropriate closure of the extraction site.[52]

Similar to maxillary third molars, the anatomical relation to vital structures is of prime importance in mandibular third molars. When the root apices of mandibular third molars show close proximity to the mandibular canal, periapical radiographs with different axial projections,[2] or preferably three-dimensional images using CBCT, are recommended.[53] Besides the darkening appearance of the root (increased radiolucency due to impingement of the mandibular canal on molar roots), changing the axial angulation would help in determining the bucco-lingual relation of the mandibular canal to the roots. If the straight on and over axial views did not result in any change in the radiographic appearance of the overlapped canal on the roots, then a very close relation would be suspected.[2] In such cases, meticulous attention should be paid to avoid over-instrumentation, broken files and extrusion of irrigants, medicaments and root canal sealers to prevent local injury to the nerve that, if occurred, would require complicated surgical intervention to prevent permanent nerve damage.[54-57]

Endodontic treatment considerations

Endodontic management of third molars with normal root/root canal anatomy

Due to the most posterior location and restricted accessibility of third molars, an easier handling of each endodontic procedure would be provided by using the following:

1. Contra-angle handpiece with a small head
2. Mouth prop for maintaining an adequate mouth opening
3. Short endodontic files (21 mm). Files with length 25 mm are only preferable in determining the working length using the electronic apex locator for better accommodation of the file holder
4. Gates Glidden drills with short shank
5. Hand spreaders for lateral compaction technique would accommodate for the limited accessibility better than finger spreaders.

Maxillary and mandibular third molars usually are tilted in distal and mesial directions, respectively. During access cavity preparation of mandibular third molars,

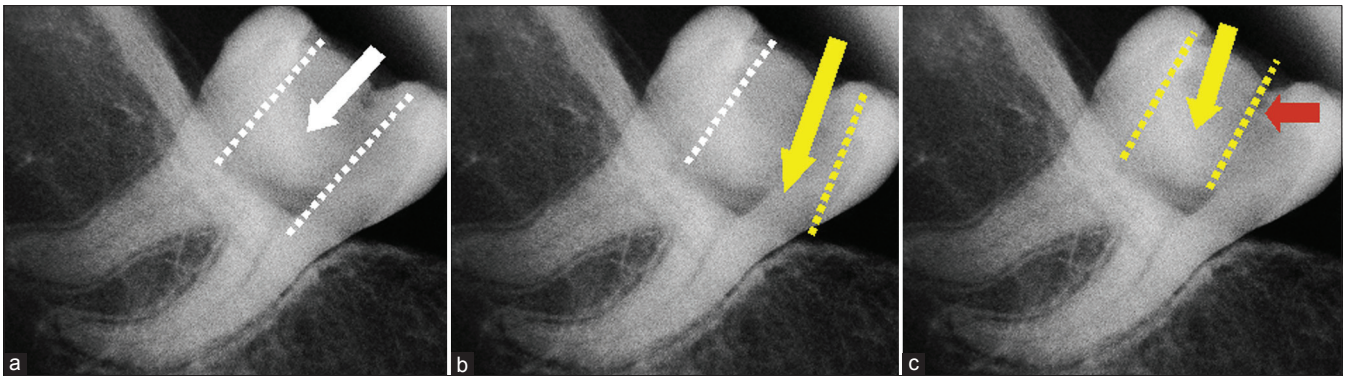

Figure 4: (a) Access cavity preparation of a mesially tilted mandibular third molar. The handpiece should be at the long axis of the tooth. (b) Inability to obtain a straight line access to the root canals would increase the risk for cervical perforation. (c) In cases where a straight line access cannot be achieved, a slight distal shifting of the access cavity would prevent the risk for perforation (red arrow)

care should be taken to place the handpiece at the long axis of the tooth to avoid mesial perforation at the cervical portion of the crown [Figure 4a,b]. In some cases, the mandibular third molar is tilted mesially and slightly below the occlusal plane of the neighboring tooth that would complicate the placement of the bur at the long axis. This would require distal shifting of the access cavity preparation to avoid mesial perforation [Figure 4c].

Endodontic management of third molars with normal root/root canal anatomy and in close proximity to a surrounding vital structure

If a close proximity of the root apex to a vital anatomical structure is observed, then the following guidelines are recommended:

Avoid infection

The carious lesion should be excavated completely, and if the proximal wall is missing, it should be restored adequately before placement of the rubber dam. The placement of the rubber dam [Figure 5], with a caulking material such as Oraseal (Ultradent, USA), would prevent re-contamination, which can be transmitted to the vital anatomical structure. Apart from that, some studies reported maxillary sinus aspergillosis as a fate of unintentional extrusion of root canal sealers, especially those containing zinc oxide and paraformaldehyde, into the sinus.[49,58,59] Despite the antifungal activity of zinc oxide eugenol sealers, their existence as foreign bodies may alter the normal function of respiratory epithelium by causing edema and impairing the ciliary movement. In addition, it may become well protected hiding places for spores.[49]

Avoid mechanical trauma

The use of an electronic apex locator and a confirmatory periapical radiograph would keep the files within the confines of the root that is not beyond the minor diameter of the apical foramen. This would prevent over-instrumentation and subsequent injury to the surrounding vital structure.

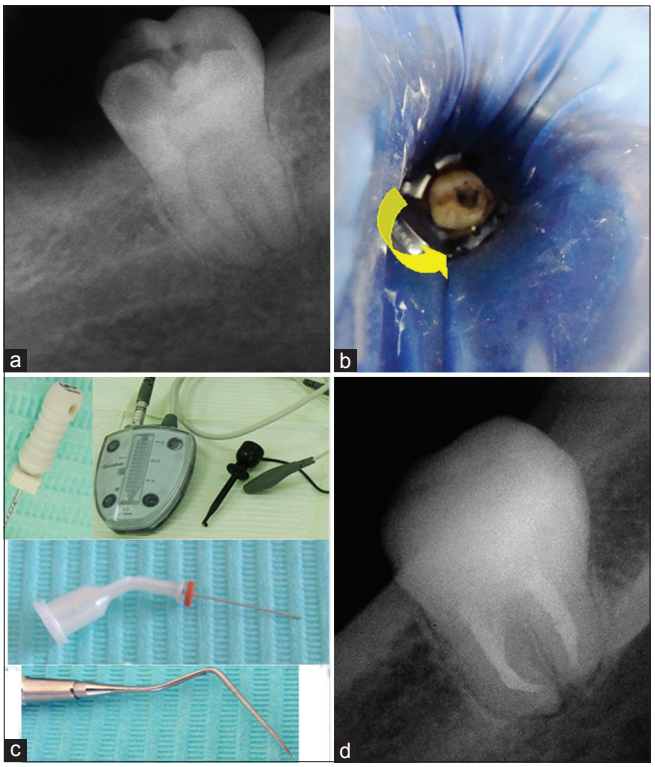

Figure 5: Endodontic management of a mandibular 3rd molar. (a) Preoperative. The mandibular canal is superimposed on the roots. (b) Rubber dam placement. The clamp was rotated to accommodate for the tilted molar. (c) Short files (21 mm), electronic apex locator, NaviTip with short length and hand spreader were used for endodontic management. (d) Post-operative. The tooth was obturated using lateral compaction technique

Caution during irrigation

Despite the deleterious effects of sodium hypochlorite (NaOCl) if injected inadvertently into either the maxillary sinus or mandibular canal, the use of NaOCl during mechanical instrumentation is mandatory to ensure optimal dissolution of inflamed/necrotic pulp tissue and proper disinfection of the root canal system. Many controversies do exist regarding the most potent antimicrobial, least cytotoxic, concentration of NaOCl.[60-63] Nevertheless, it seems that a slow and constant delivery

of sodium hypochlorite at lower concentrations (<2.5%) using a suitable sized irrigation needle, that is not wedged inside the canal, would be safe unless the root apex is immature or resorbed. In such cases and due to loss of normal apical constriction and high possibility for extrusion, the delivery of NaOCl, at 0.5% concentration, using side vented needles or negative pressure irrigation systems such as EndoVac (Discus Dental, USA), would reduce the risk for post-operative complications.[54,63,64]

Avoid chemical/pressure irritation

Perforation of the maxillary sinus by gutta-percha or silver cones, as well as injection of calcium hydroxide medicament into the sinus has been reported to cause various inflammatory responses.[49,65,66] In addition, the extrusion of sealer and/or gutta-percha into the mandibular canal space is the most common cause for post-operative toxic reactions in the mandibular canal ranging from mild inflammatory reactions to ischemia and disabling sensory disturbances, such as paresthesia, dysesthesia and anesthesia, which may become permanent.[67-70] Indeed, the extrusion of toxic chemicals, such as paraformaldehyde containing pastes, calcium hydroxide medicament and eugenol based sealers, would cause more damage and delay of the recovery potential.[70,71]

To minimize the risk for extrusion, it is recommended to obtain: 1) An optimal apical stop. 2) A snugly fitting master gutta-percha cone. 3) The root canal sealer should be prepared in a creamy consistency, and applied in a small amount. 4) Avoid the application of sealer onto the tip of master gutta-percha cone if the roots are in the vital structure. 5) Excessive lateral compaction forces should be avoided.

Avoid thermal insults

An uncontrolled manipulation of thermoplasticized gutta-percha may cause thermal insults to soft and hard tissues. Gross extrusions of thermoplasticized gutta-percha into the maxillary sinus and mandibular canal have been reported.[72,73] Apart from the thermal insult of this technique, it also comprises a mechanical component which would make the injury to the inferior alveolar nerve not only a transient noxious reaction. The use of thermoplasticized gutta-percha in third molars is not a common procedure due to lack of space for proper accommodation of delivery tips and pluggers. However, if the space is adequate, this technique can only be used for backfilling, after adjusting and down packing a snugly fitting master gutta-percha cone in a well prepared apical stop.

Endodontic management of third molars with abnormal root/root canal anatomy

Dilacerated roots

The root canal treatment of dilacerated roots presents an endodontic challenge. All the recommended guidelines for treating such canals should be followed including unobstructed, straight line access to the apical foramen as much as possible.[8,26] This can be achieved by removing the coronal dentin shelf and the outer canal tooth structure using anti-curvature filling or Gates Glidden burs. This coronal flaring, before apical preparation, would also reduce the stresses on the file, and allow more penetration of the irrigation needle to deliver NaOCl for better tissue dissolving effect, antimicrobial activity and lubrication. In addition, the working length determination would be more accurate.[74]

Pre-curvature of flexible stainless steel hand files, with non-cutting tips, is essential in maintaining the normal canal configuration, especially in narrow canals, thus preventing ledging, zipping and transportation. In addition, the application of incremental instrumentation techniques by adding intermediate sizes while performing mechanical instrumentation, especially in narrow canals, also would provide gradual increase in the apical preparation, thus reducing the original root canal shape alteration and minimizing the stresses on the enlarging files.[75,76] The use of suitable sized irrigation needles and lubricants also is helpful.[76]

Despite the greater flexibility of nickel titanium (NiTi) files and their ability to maintain root canal curvatures in many teeth, they usually are not suitable for treating dilacerated root canals, especially when they also are

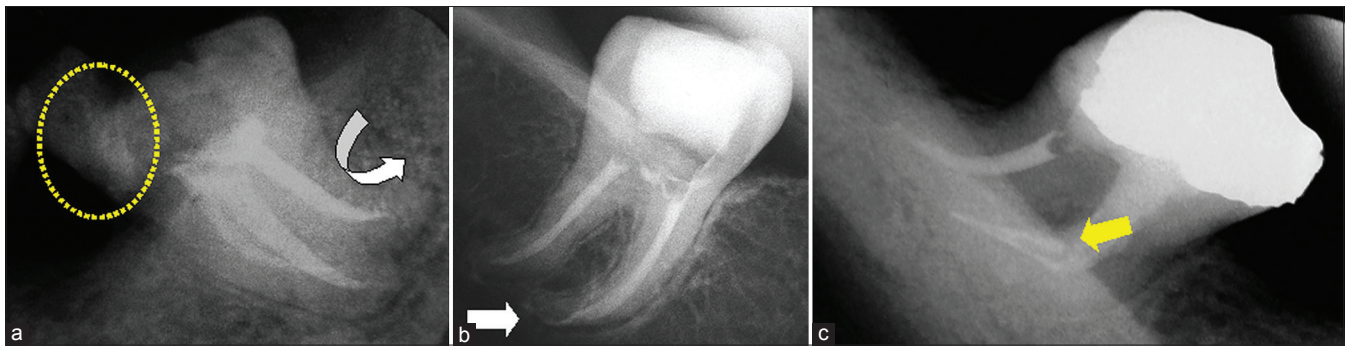

Figure 6: Intraoperative complications during endodontic treatment of third molar teeth. (a) Mesial cervical perforation and inability to maintain the normal configuration of the root canal. (b) Ledging, zipping and apical perforation due to inability to maintain the curvature of the mesial root canal. (c) Broken NiTi file in the mesial root, which was encasing narrow mesial canals. Note the successful management of the wide distal root canal, despite the dilaceration

narrow.[26] This is due to their inherent elastic property that would not accept any "sharp bend" for better negotiation into the "abrupt" curvature of the dilacerated root. As a result of the severe extent of the curvature that must be negotiated by NiTi files, more stresses would be exerted on the file, thus increasing the possibility for file separation [Figure 6c], unless the canal is relatively wide [Figure 6c].

The obturation of such canals can be performed by lateral compaction technique using flexible NiTi spreaders that would penetrate into greater depths and distribute forces more evenly than stainless steel spreaders.[26]

C-shaped canals

C-shaped canals present another critical endodontic challenge, both at the diagnostic and treatment levels.[77] Despite their unique anatomic features, including the presence of calcifications, curvatures, root canal bifurcations, transverse anastomoses, lateral canals, and apical deltas, a well-prepared access cavity and thorough intra-radicular exploration would aid in identifying the complex internal morphological features of C-shaped canals,[78,79] that are not easily detected in conventional periapical radiographic views.[80] Careful exploration with a small, pre-curved file along the root canal walls under magnification and co-axial illumination is essential for characterizing the category of the C-shaped canal.[5,81,82]

With the exception of the isthmus, the root canals can be prepared normally. The isthmus should not be prepared with either Gates Glidden burs or hand files larger than size 25 to prevent strip perforation.[78] Owing to the inherent instrumental limitations and the well-protected environment provided by this anatomical variation to microorganisms, the use of NaOCl at concentration 5.25% would enhance the debridement of these narrow canal isthmuses.[78] However, if the root is in close proximity to a vital structure, a low concentration would be used, but for longer time. Ultrasonics irrigation and the use of different designs of rotary nickel titanium files such as self adjusting files (ReDent, Israel) have been advocated to enhance the cleaning ability of these canals.[5,77,78,83]

The obturation of C-shaped canals may require different manipulation.[78] A sufficient chemo-mechanical preparation of C-shaped canals would facilitate the penetration of root canal cements into the isthmus area during lateral compaction. However, the use of thermoplasticized gutta-percha would be the most appropriate.[5,78,79,84] This would be applied in third molars, if there is enough space for the delivery tips and hand pluggers.

Endodontic management of third molars with abnormal root/root canal anatomy and in close proximity to a surrounding vital structure

This is the most challenging clinical situation, especially if the accessibility is restricted. The operator should evaluate his ability to manage such cases, which is better to be referred to a more experienced endodontist. Otherwise and if the case is vital, other treatment options such as pulpotomy might be indicated.

II) Pulpotomy

Vital pulp therapy via pulpotomy is the partial or complete amputation of the coronal pulp tissue, and capping the remaining pulp tissue with a suitable material.[85] This treatment approach has been reported to provide more predictable outcomes than direct pulp capping.[86] Despite its usual indication for treating deciduous teeth, recently, some clinical investigations and reported cases have demonstrated successful clinical applications in permanent teeth, including third molar teeth, with immature and mature root apex using biocompatible capping materials such as mineral trioxide aggregate (MTA) (Dentsply, USA) and calcium enriched mixture cement (Bionique, Iran).[85,87-92]

As a result of these favorable clinical outcomes and more conservative approach than total pulpectomy, in some clinical situations, this would provide an easier treatment option for third molar teeth with very difficult accessibility, extremely complex root canal morphology and those with very close proximity to a surrounding vital structure. However, this treatment approach is not indicated for badly decayed third molars that require restoration via post and core. In addition, the retreatment of such cases would be extremely difficult. That's why if the tooth is accessible, and/or planned to be an abutment in a fixed prosthesis, a conventional root canal treatment would be preferred.

III) Autogenous transplantation

Autogenous tooth transplantation (autotransplantation) is defined as the transplantation of a tooth, either with complete or incomplete root formation, from one site to another in the same individual.[93,94] The success rate of this treatment approach varies according to the surgical procedure, splinting method and fixation periods.[95-97] However, if the treatment procedures are performed accurately, the success rate can reach over 90%.[95,97] Accordingly, this treatment approach, after careful assessment, can be considered as a viable alternative to conventional prosthetic and implant rehabilitation from therapeutic and functional outcomes and more importantly, from economic standpoints.[98,99] In addition, an auto-transplanted tooth would preserve the amount and quality of alveolar bone, thus permitting later insertion of a implant, if indicated.[99]

Third molars are potentially reliable candidates to replace badly decayed or missed first or second molars, as well as premolar teeth.[100] Indeed, a modification of the recipient socket or amputation of one or two roots of the donor tooth is sometimes required for better accommodation.[97,100] Interestingly, cryopreservation and

storage in a tooth bank have shown a potential clinical application when the tooth can not be transplanted immediately.[101-103]

Root canal treatment is usually recommended, in mature teeth, 3 to 4 weeks after autotransplantation to avoid the undesirable consequences following pulp death and root resorption.[96,99,104] Some authors recommend the application of calcium hydroxide for some weeks prior obturation.[104] In contrast, a recent study by Waikakul *et al.*[98] reported a high success rate, after follow-up of one year, following autotransplantation without endodontic treatment indicating that endodontic treatment of the autotransplanted teeth is unnecessary, even when the apex is closed. Although their study included only 7 out of 54 teeth with close apex, this approach may be useful for patients who cannot afford for the endodontic treatment.[97]

The prognosis of autotransplantation is favorable as long as the case is selected precisely, the surgical procedure is performed as atraumatic as possible and the patient is able to follow the post-operative instructions and maintain good oral hygiene measures.

CONCLUSIONS

Besides their existence as a functional component in the dental arch, third molars may serve as a convenient abutment for a prosthetic restoration, and potentially reliable candidates for autotransplantation. Therefore, whenever indicated, the retention of third molars should be preferred. However, due to anatomical challenges, an accurate perception and absolute clinical thoroughness are warranted to avoid the occurrence of serious complications while commencing endodontic treatment in third molar teeth.

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