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· 专家论坛 ·

中国人群上颌第二磨牙变异根管发生率及治疗策略分析

冯晓黎, 孙书昱

南方医科大学口腔医院牙体牙髓科, 广东 广州(510280)

【摘要】 上颌第二磨牙牙根及根管系统解剖形态复杂且变异多见, 导致对其进行根管治疗难度较大, 甚至会出现治疗失败。因此, 了解上颌第二磨牙牙根及根管解剖形态的多样性是成功治疗的前提。融合根是上颌第二磨牙最常见的牙根变异类型之一, 在国内人群中其发生率在 23.9% ~ 42.25%。融合根常伴有复杂的根管融合, 在国内人群中上颌第二磨牙 VI 型融合根中融合根管发生率可达 90.5%。针对上颌第二磨牙变异根管的治疗策略, 主要包括根管口定位、融合根管峡区清理及充填等方面。临床上对融合根变异根管口进行定位时, 可联合应用锥形束 CT、牙科手术显微镜、数字化动静态导航技术等辅助手段。在根管治疗过程中, 对于融合根管峡区的清理及充填, 应加强化学预备, 适时采用激光辅助根管冲洗、光动力治疗, 以及显微根尖手术都将有效提高变异根管的治疗成功率。本文对中国人群上颌第二磨牙变异根管发生率及治疗策略进行分析, 以期为临床上颌第二磨牙牙髓及根尖周疾病的成功治疗提供参考。

【关键词】 上颌第二磨牙; 根管变异; 融合根; 根管口定位; 峡区; 根管治疗; 锥形束 CT; 牙科手术显微镜; 数字化导航技术

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Treatment strategy analysis and prevalence of root canal variation of maxillary second molars from a native Chinese population FENG Xiaoli, SUN Shuyu. Department of Endodontics, Stomatological Hospital, Southern Medical University, Guangzhou 510280, China

Corresponding author: SUN Shuyu, Email: sunshuy1095@126.com, Tel: 86-20-84418217

【Abstract】 The anatomical morphology of root canal systems in maxillary second molars (MSMs) is complex and shows diverse variations, which leads to challenging root canal treatments that could end in failure. Therefore, understanding the diverse nature of root canal anatomy is an important prerequisite for the successful treatment of MSMs. The fused root is among the most prevalent root variants of MSMs, exhibiting a distribution rate ranging from 23.9% to 42.25% within the Chinese population. Fused roots are often accompanied by complex root canal fusion, as the incidence of root canal fusion in type VI fused roots of MSMs is 90.5% within the Chinese population. There are several treatment strategies for the root canal variations in MSMs, including the location of the root canal orifice and clearing and filling of the isthmus within the fused root canal. Cone-beam computed tomography, dental operating microscopy, and digital dynamic and static navigation technologies can be employed to accurately identify the root canal variations associated with fused roots. In the treatment of fused root canals, for the cleaning and filling of the isthmus in fused canals, enhanced chemical preparation, timely application of laser-assisted irrigation, photodynamic therapy, and micro-apical surgery significantly improve the success rate of endodontic procedures. The treatment strategies and prevalence of root canal variation of MSMs from a native Chinese population were summarized in this paper to provide guidance

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【作者简介】 冯晓黎, 副研究员, 博士, Email: fxl226@smu.edu.cn

【通信作者】 孙书昱, 主任医师, 博士, Email: sunshuy1095@126.com, Tel: 86-20-84418217

and reference for the successful treatment of MSMs.

【Key words】 maxillary second molars; root canal variation; fusion roots; location of root canal orifice; isthmus; root canal treatment; cone-beam computed tomography; dental operating microscopy; digital navigation technologies

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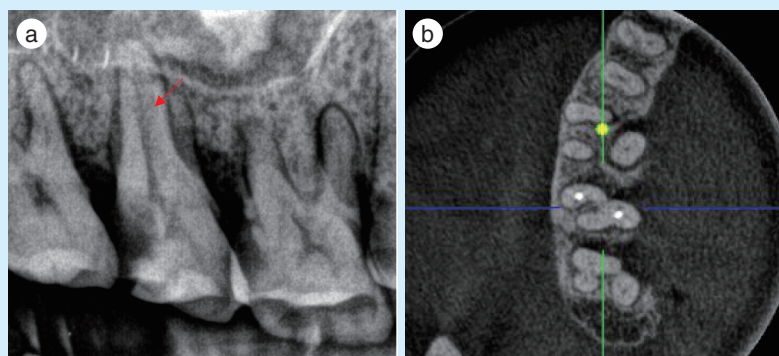
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上颌第二磨牙(maxillary second molars, MSMs)位于牙列的后端,因难以清洁使其罹患牙髓疾病及根尖周疾病的概率较高。同时,上颌第二磨牙的牙根及根管系统解剖形态复杂、变异情况多见,导致对其进行根管治疗的难度明显增加^[1-3]。因此,了解上颌第二磨牙的牙根及根管解剖形态的多样性是成功治疗的重要前提。融合根是上颌第二磨牙最常见的牙根变异类型之一^[4-6]。其中,近颊根(mesiobuccal root, MBR)与腭根(palatal root, PR)之间的融合最为普遍,也可发生远颊根(distobuccal root, DBR)与PR融合或MBR、DBR融合;MBR、DBR和PR融合成一个锥形根的情况最少见^[6]。牙根的融合常伴随根管系统的变异,融合根中融合根管的发生率可高达69.5%^[7],且融合的牙根数量越多,根管类型可能越复杂^[8]。这些因素导致在对上颌第二磨牙进行根管治疗时,会出现根管口定位困难、融合根管峡区难以彻底清理及充填不到位等难题,进而导致治疗失败。笔者总结了国内人群上颌第二磨牙融合根及其根管系统解剖形态的分布及发生率。同时,针对上颌第二磨牙融合根及其变异根管的治疗策略进行了分析和探讨,以期为临床上颌第二磨牙的牙髓及根尖周疾病的成功治疗提供理论指导和实践参考。

1 上颌第二磨牙融合根分布及发生率

国内人群上颌第二磨牙牙根以三根型最常见,发生率为67.12%~88.62%^[9-10],此外,还可出现单根型、双根型融合根及四根等情况^[11]。从釉牙骨质界开始,根分叉的最低点到釉牙骨质界的高度大于根长1/3的牙根定义为融合根^[12]。融合根是上颌第二磨牙常见的牙根变异类型,国内人群中发生率为23.9%~42.25%^[2,8,13]。上颌第二磨牙融合根在传统牙片上较难被准确识别,目前学者们多采用锥形束CT(cone-beam computed tomography, CBCT)对其进行观察和研究(图1)。Zhang等^[8]根据融合的牙根数及类型将其分为以下6型:I型:MBR与DBR融合;II型:MBR与PR融合;III型:DBR与PR融合;IV型:MBR与DBR融合,PR与MBR或DBR融合;V型:PR分别与MBR和DBR融合;VI型:PR、MBR及DBR融合成一个整体。其中,I型和II型融合根最常见,III型和VI型比较少见^[6,8]。笔者团队收集了近1700例上颌第二磨牙的CBCT资料,其融合根横断面影像学表现如图2所示。根据影像学表现,笔者将融合根情况分为7型,3大类。具体如下,第1类为MBR、DBR、PR的两两融合(图2a~2c);第2类为其中两根分别和第3根融合(图2d~2f);第3类为三根融合成一锥形根



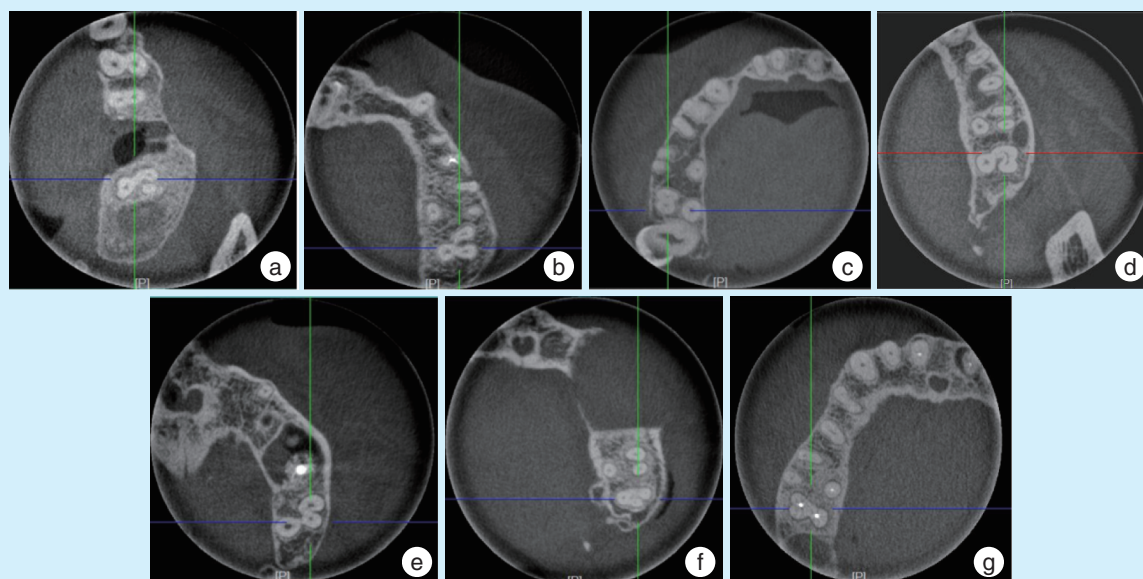
a: traditional dental film indicating suspected fusion of the buccal roots of the right MSM (arrow); b: cross-sectional image (obtained via CBCT) illustrating that the MBR and DBR are integrated with the PR. MSM: maxillary second molar; CBCT: cone-beam computed tomography; MBR: mesiobuccal root; DBR: distobuccal root; PR: palatal root

Figure 1 X-ray film and CBCT image findings of the fused roots of MSMs

图1 上颌第二磨牙融合根在牙片和CBCT影像学表现

(图 2g)。目前研究认为上颌第二磨牙融合根的分
布具有对称性,融合根的发生率随着年龄的增长

而增加,而女性的融合根发生率高于男性^[7, 14]。



a: fusion of the MBR and PR; b: fusion of the DBR and PR; c: fusion of the MBR and DMR; d: MBR fused with the DBR and PR; e: DBR fused with the MBR and PR; f: PR fused with the MBR and DBR; g: fusion involving the MBR, DBR, and PR. MSM: maxillary second molar; CBCT: cone-beam computed tomography; MBR: mesiobuccal root; DBR: distobuccal root; PR: palatal root

Figure 2 CBCT image findings of the cross-section of fused roots in the MSM

图 2 上颌第二磨牙融合根横断面的 CBCT 影像学表现

2 上颌第二磨牙融合根管解剖形态

2.1 根管系统分类

上颌第二磨牙的根管分布从 1~6 个不等,其
中,3 管型最常见^[13]。Vertucci 分类法^[15]根据单根

内根管从根管口至根尖的走形,将根管形态分为
8 类(图 3)。该方法详细描述了单根内根管的走
形,并展示了根管系统的复杂性,是目前国际上最
常采用的根管分类方法之一。

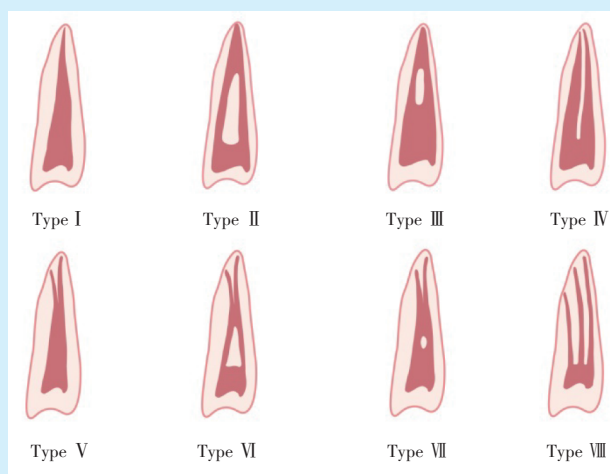


Figure 3 Diagram illustrating the Vertucci classification for dental canals^[15]

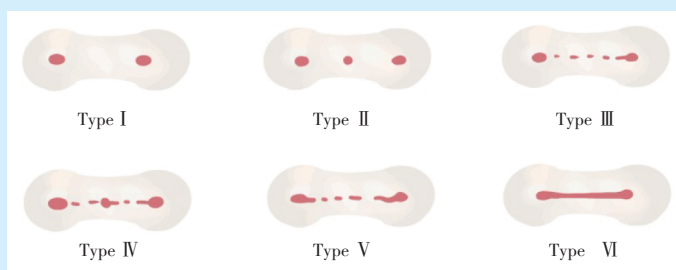
图 3 牙根管 Vertucci 分类示意图^[15]

Type I: Type 1-1 is characterized by a single canal with one apical foramen. Type II: Type 2-1 features two root canal openings that fuse at one-third of the apex, with a single apical foramen. Type III: Type 1-2-1 consists of one root canal opening where one-third of the root divides into two canals, which then converge to form a singular apical orifice at the tip. Type IV: Type 2-2 is identified as a single double-tube configuration with two tubular openings that lead to the apex and possess two distinct apical foramina. Type V: Type 1-2 comprises one root canal opening located at one-third of the apex that leads to the formation of two apical foramina. Type VI: Type 2-1-2 exhibits two root canal orifices where one-third of the root is divided into two canals and further bifurcated at the apex into two separate apical foramina. Type VII: Type 1-2-1-2 involves a single root canal opening where one-third of the root splits into two canals that subsequently merge together before dividing again at the apex to create two distinct apical foramina. Type VIII: Type 3-3 is defined as a single tritubular structure containing three separate apical foramina

2.2 融合根管及峡区

牙根融合常发生于牙根发育期,由于上皮根鞘弯折形成的上皮隔舌状突起增殖停滞未融合所致,上颌第二磨牙融合根常伴随根管融合的发生。相艳等^[7]报道,闽南地区人群上颌第二磨牙融合根中融合根管的发生率达69.5%;其中,Ⅵ型和Ⅰ型融合根的融合根管发生率最高,分别为90.5%及84.4%,Ⅴ型融合根的融合根管发生率最低,为22.2%。融合根的融合类型与根管变异有一定相关性,融合的牙根数量越多提示根管类型越复杂。例如,Zhang等^[8]发现,上颌第二磨牙独立PR最多,独立MBR最少,提示MBR融合的发生率最高,并且其根管类型包含了VertucciⅠ、Ⅱ、Ⅲ、Ⅴ型。

根管峡区是存在于同一牙根内、两根管间,含有牙髓或牙髓来源组织的一种狭窄带状结构^[9]。上颌第二磨牙含有多根管的牙根,包括各型融合根及单独的MBR都可能存在管间峡区。有研究报道,上颌第二磨牙的MBR双根管中存在管间峡区时,其在距离根尖3~5 mm处发生率最高,在距根尖4 mm处的发生率近100%^[16]。根据Hsu & Kim分类^[17],根管峡区分为部分峡区及完全峡区两大类(图4),其中,部分峡区又细分为Ⅰ~Ⅴ型。峡区内坏死牙髓组织、感染微生物及其代谢产物的清理不完善,是导致根管治疗失败的主要原因之一。因此,熟悉根管峡区的部位及形态对于根管清理和显微根尖手术均具有重要意义。



Partial isthmus: Type I and II exhibit no significant connections between two or three root canals. Type III presents hair-like small connections between two root canals. Type IV reveals small hair-like connections among three root canals. Type V indicates that root canals extend into the isthmus. Complete isthmus: Type VI features a narrow band connection between two canals

Figure 4 Root canal isthmus types (Hsu & Kim classification^[17])

图4 根管峡区类型(Hsu & Kim分类^[17])

3 变异根管口定位

融合根内常伴随融合根管的发生,此时,根管口位置可发生偏移。准确定位到根管口是根管清理的第一步。临床上找寻上颌第二磨牙变异根管口的策略归类如下,对下述手段的综合应用将有助于成功定位到上颌第二磨牙根管口。

3.1 CBCT应用

CBCT是发现和识别牙根融合及根管变异的有力工具。与传统的根尖片、曲面断层片相比,它能够三维的重建影像,使临床医生在根管治疗术前、术中观察不同角度及层面的影像,清楚了解根管的数目、形态、融合及钙化等情况。研究显示降低CBCT拍摄的立体像素能增加分辨率,有利于进行根管探查,进而提高MB2根管口的发现率。降低CBCT拍摄时的立体像素还能减少对患者的辐射剂量^[18]。有学者建议在牙体牙髓治疗拍摄CBCT时,可选用最小视野且扫描角度不小于180°,从而获取更高清的图像^[19]。

3.2 牙科手术显微镜应用

上颌第二磨牙牙根及根管系统存在较多变异

类型,甚至会出现“假性根管口”。牙科手术显微镜已被广泛应用于传统和外科牙髓及根尖周病的治疗领域。其通过聚焦光源及有效放大视野,使术者能够更清晰观察到根管的细微变化,使根管口定位更加准确(图5)。在利用牙科手术显微镜找寻上颌第二磨牙变异根管口时,应当关注根管口的解剖分布特征,从而节省治疗时间,达到事半功倍的效果。黎祺等^[2]在研究的1 220颗上颌第二磨牙中发现有68颗牙齿为单根型融合根,其中以Vertucci分类中Ⅷ型根管最多,占63.25%。此型3个根管口相距不超过2 mm。此外,治疗中若发现腭根管(palatal canal, P)根管口未在髓底腭侧的中间,而是偏于一侧,且根管口缘向另一侧延伸,应沿髓底沟向另一侧扩展,使髓底沟充分暴露,寻找其他可能存在的、位置隐蔽的根管口,以免遗漏根管^[11]。随着年龄的增长,牙齿会发生各种增龄性改变包括继发性牙本质形成、根管钙化等。研究发现,增龄性变化会导致近中颊根管(mesio-buccal canal, MB)根管口位置的改变,表现为MB与第二近中颊根管(mesio-buccal 2 canal, MB2)、远中颊根

管(distal-buccal canal, DB)根管口间的距离逐渐变小;DB和P根管口之间的距离则相对稳定^[18]。Krasner等^[20]总结的根管口分布规律也同样适用于上颌第二磨牙根管口的找寻:根管口位于髓室底

和髓腔壁交界;根管口位于髓室底和髓腔壁的交界成角度处;如果存在发育形成的牙根融合线(髓室底沟),根管口位于此线的终端;并且,发育的牙根融合线颜色深于髓室底的颜色。

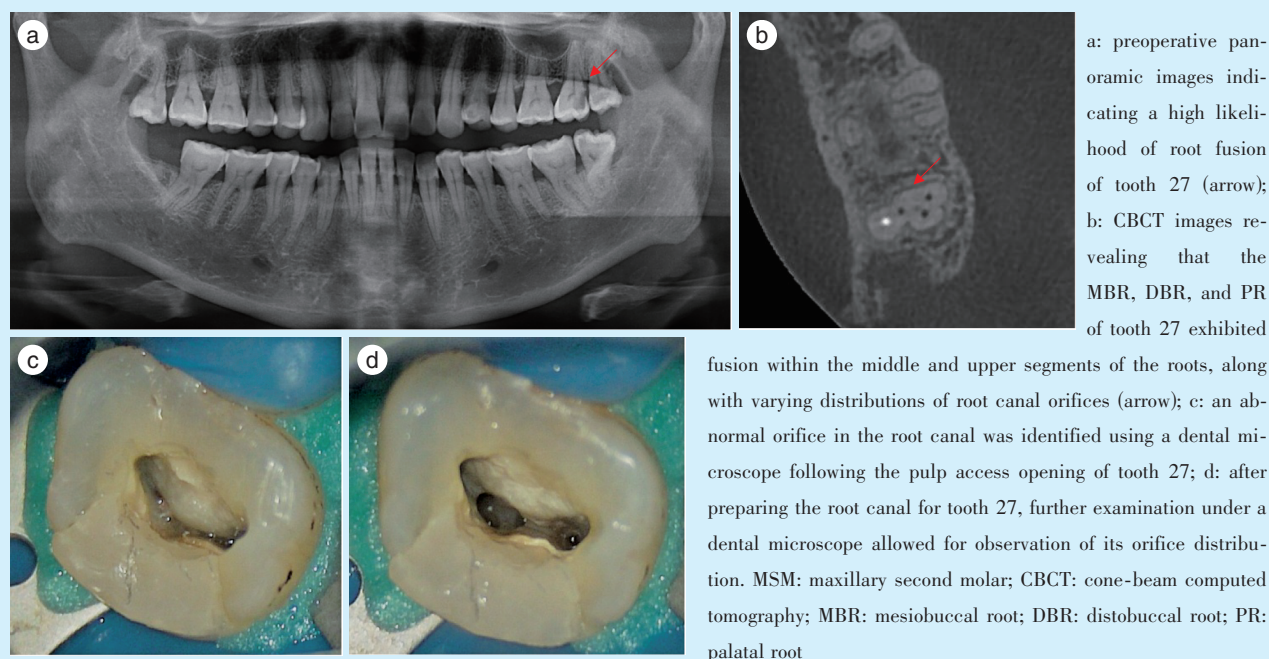


Figure 5 CBCT-assisted dental operating microscopy for the detection of root canal variations in MSMs

图5 CBCT辅助牙科手术显微镜下寻找上颌第二磨牙变异根管口

3.3 数字化导航技术

随着数字化信息的发展,动静态导航技术为治疗疑难复杂的牙髓根尖周病提供了新的思路和方法。

静态导航技术,又称为数字化导板技术,首先利用CBCT扫描获得患者的口内数据,通过软件分析、设计并3D打印数字化导板,用于指导术者的手术器械及涡轮机使用。在根管治疗中,数字化导板技术多用于辅助开髓以及根管通路的建立^[21]。例如,数字化导板可依据根管体表投照设计开髓入路,使器械精确抵达根管口,避免过多磨除牙体组织量的同时节省手术时间^[22]。此外,钙化根管由于发生硬组织的沉积,根管口变得狭窄甚至堵塞;数字化导板技术可通过软件分析更加精确地定位到钙化根管口并辅助疏通钙化根管^[23-25]。数字化导板技术还被报道用于解剖变异牙如牙内陷的根管治疗^[26]。

与数字化导板技术相比,动态导航技术不需要预先打印导板,术中可根据显示器的反馈及时

发现并纠正操作错误,达到更加理想的治疗效果^[27]。由此可见,数字化导板技术及动态导航技术在设计不规则髓腔的精准开髓及定位变异根管口方面也具备较大潜力。上颌第二磨牙根管系统复杂,且位于牙弓后方导致治疗视野差,术中操作易受到患者开口度的影响。应用动态导航技术,既不需要套筒导板的额外空间,又可在术中实时指导和调整术者操作,是辅助上颌第二磨牙根管治疗的有力工具。然而,由于:①动态导航技术经济成本昂贵,目前尚缺乏专门针对根管治疗的导航系统;②其对术者的临床操作较传统治疗具有更高要求;③现有影像系统仍存在信息滞后、系统误差等不足,动态导航技术在根管治疗中的应用仍相对局限,主要集中于疑难根管的开髓^[28-29]、疏通^[30]及分离器械取出^[31-32]等。

3.4 超声器械应用

上颌第二磨牙位于牙弓的末端位置,在治疗中更多地受限患者张口度,从而增加了视野盲区,加重了治疗难度。在治疗中应仔细探查髓室

底,必要时可扩大髓腔开口以开阔视野,便于找寻隐蔽位置处根管口。近年来,为了避免高速涡轮球钻磨除牙本质过程中造成髓室壁或根管壁的穿孔,出现了各种新型超声器械,例如ET18、ET20等用于寻找并疏通细小、钙化根管^[33]。借助牙科手术显微镜利用超声工作尖清除髓腔内及根管口钙化物,可更加准确地定位到根管口、避免遗漏钙化根管,在提高治疗安全性的同时缩短了临床操作时间。

4 根管峡区治疗策略

Endal等^[34]采用Micro-CT研究发现,35.2%的峡区预备后会被牙本质碎屑堵塞,进一步导致根充后峡区中的充填材料仅占其体积的57.7%,显著低于主根管的充填密度(98.5%)。牙本质碎屑混合了细菌及其代谢产物黏附至根管壁并形成玷污层,从而为根管内微生物持续提供营养,管间峡区也成为感染持续存在的隐蔽部位^[35]。常规根管治疗难以对根管峡区进行彻底的机械清理、成形及充填,同时含有峡区的牙根多呈扁形,根管牙本质壁较薄,容易发生过度切削、带状穿孔甚至根裂的可能,因此微创预备根管峡区的同时应注重加强化学冲洗,对峡区进行彻底清理;采用根尖手术时,结合牙科手术显微镜行根尖倒充填能达到更加理想的充填效果。

4.1 化学消毒

在机械预备不能涉及的部位,利用化学冲洗剂的消毒作用可进一步实现清除感染的目的。目前,临床上最常使用次氯酸钠(NaOCl)溶液作为根管冲洗剂,其具备良好的杀菌能力和有机组织溶解能力,但也存在细胞毒性较大^[36]、理化性能不稳定等不足^[37]。新型冲洗剂QMix由氯己定、EDTA和表面活性剂等组成,兼有良好的抗菌性能及无机物脱矿效果,同时表面活性剂成分还可提高根管壁的湿润性,促进冲洗液渗入根管^[38]。还有研究报道MTAD冲洗液可有效杀灭主根管中悬浮状态的大部分细菌,包括易导致根管治疗失败的粪肠球菌^[39]。然而,包旭东等^[40]也发现尽管MTAD可渗入根尖区管间峡部,但杀菌效果较弱;并进一步指出次氯酸钠配合EDTA冲洗仍然是清除峡部感染的最优方案。近年来,更多研究关注于冲洗技术的提升,动能冲洗理论应运而生。王思祁^[41]比较了传统冲洗器冲洗、超声冲洗、声波冲洗及激光冲洗4种方法在C形根管中的渗透能力,并发现

动能冲洗效果均显著高于传统冲洗器;其中,激光冲洗效果最好。在管间峡区,超声冲洗渗透能力明显减弱,但激光冲洗和声波冲洗仍具有一定的渗透能力。目前,大部分研究支持动能冲洗对管间峡区的清理效果明显高于传统冲洗器,然而最佳的动能冲洗方式和冲洗条件仍需要进一步探讨。

4.2 光动力疗法

扫描电镜观察到,感染根管内细菌可侵入牙本质小管内1 000 μm 或更深处,临床上常规使用的冲洗液包括NaOCl等均不能到达该位置。为进一步提升根管消毒水平,光动力治疗(photodynamic therapy, PDT)逐渐受到更多研究者的关注。PDT是一种对硬组织或软组织部位局部应用光敏化合物进行消毒或灭菌的方法,包括光敏剂、光源和氧三个基本要素。光敏剂受到特定波长的光照射后,产生活性氧分子并与细胞或微生物的磷脂、核酸等生物大分子反应,通过破坏生物膜结构或其他功能单位使细胞或微生物死亡。有报道使用姜黄素和纳米姜黄素作为光敏剂辅助光动力疗法可有效清除根管内粪肠球菌^[42]。Tennert等^[43]同样证实单独使用PDT可使根管内粪肠球菌数量减少92.7%,PDT联合NaOCl冲洗可使粪肠球菌减少99.9%。不仅如此,与机械化学清创及机械化学清创+激光消毒相比,机械化学清创+PDT能更有效地清除粪肠球菌生物膜,并且对根管冠、中、根尖1/3未成熟生物膜和成熟生物膜均有较好疗效^[44]。融合根管的治疗难度很大程度上取决于治疗器械难以进入峡区,那么,基于光源PDT的应用则具备较大优势。然而,目前关于PDT直接应用于上颌第二磨牙融合根管的临床研究仍比较匮乏,尚需要更多的研究数据来论证该推论。

4.3 显微根尖手术

朱丽娜等^[45]针对110例根尖区存在峡区的上颌第一前磨牙进行临床研究,发现常规根管治疗对完全峡区和部分峡区均不能严密充填,然而根尖倒充填均能达到良好的封闭效果。结果提示,采用显微根尖手术行根尖倒充填对于根尖部峡区充填更具有优势。术前通过CBCT扫描及三维重建,可准确评估管间峡区在根尖部的位臵,从而有利于显微根尖手术清除根尖感染、促进根尖周病变愈合^[46]。目前关于上颌第二磨牙管间峡区行显微根尖手术的临床研究仍比较缺乏,这可能是由于上颌第二磨牙位于牙弓后方,进一步增加了手

术难度所致,必要时可考虑意向再植术完成根尖峡区的清理和严密充填。

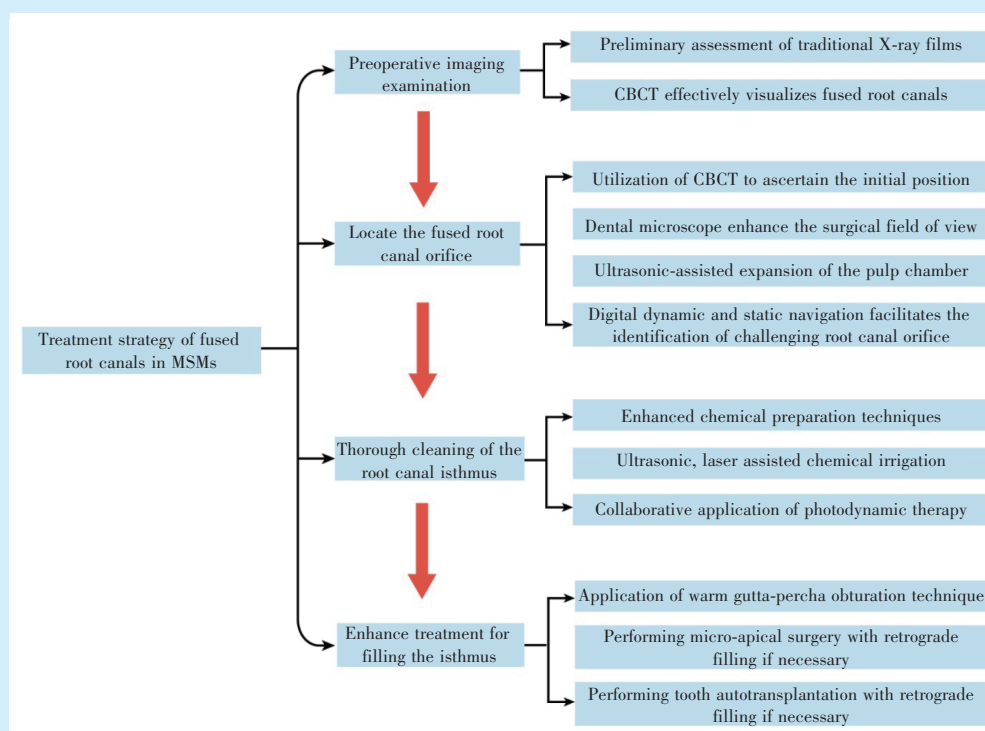
5 上颌第二磨牙融合根管治疗预后

2024年,一项临床研究对1 259颗成熟恒牙(2 445个牙根,3 149个根管)进行了根管治疗或根管再治疗术后1~4年的随访。结果显示:外伤史,严重的根尖周炎,复杂的根管解剖结构,一次根充效果不理想(包括充填质量不满意、根充材料距根尖 $>2\text{ mm}$ 、未使用生物陶瓷糊剂),上部冠修复质量欠佳是影响根管治疗预后的关键因素^[47]。其中,与融合根管治疗密切相关的因素就包含了2项,即复杂的根管解剖结构及根充效果不满意。此外,目前已有的证据显示,根管治疗中出现遗漏根管、根管穿孔、根管偏移等问题也会导致根管治疗的失败^[48]。融合根管多呈带状根管,内含峡区等隐蔽结构,极大增加了根管机械预备及根充的难度;在操作中容易发生过度切削、穿孔甚至根裂的可能,最终导致根管治疗的失败。因此,熟知上颌第二磨牙根管系统的解剖结构,在治疗术前、术中综合应用上述策略彻底清除感染、预防医源性并发症是提高上颌第二磨牙根管治疗成功率的关键。目前,临床上针对上颌第二磨牙融合根管治

疗预后的研究尚存在较多空白,仍需要更多的研究数据来论证治疗效果。

6 结束语

充分掌握牙根及根管系统的解剖形态是保证根管治疗成功的重要前提。上颌第二磨牙融合根发生率高且多存在复杂形态的融合根管,极大增加了根管口定位、根管清理和充填操作的难度。临床上在找寻融合根变异根管口时,可视情况综合应用CBCT、牙科手术显微镜等辅助手段,必要时采用数字化动静态导航技术协助定位根管口。此外,上颌第二磨牙融合根管根尖区多见管间融合。利用超声设备协助扩大根管冠方,可进一步开阔手术视野、避免遗漏钙化等变异根管,同时提高治疗安全性。在进行根管清理时,除注重规范的机械预备外,还需要加强对融合根管的化学消毒。新型的根管冲洗技术如激光或超声导向的根管冲洗,或联合PDT,相较传统的化学冲洗方式具有更理想的杀菌效果。值得注意的是,在存在严重根尖周病变或冠方修复不适合拆除时,显微根尖手术或者意向再植术行根尖倒充填也是提高治疗成功率的有效手段(图6)。



CBCT: cone-beam computed tomography; MBR: mesiobuccal root; DBR: distobuccal root; PR: palatal root; MSM: maxillary second molar

Figure 6 Fused roots and the corresponding root canal treatment strategy of MSMs

图6 上颌第二磨牙融合根及其融合根管治疗策略

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【作者简介】 冯晓黎,副研究员,博士,硕士研究生导师,南方医科大学口腔医院牙体牙髓病科。兼任粤港澳大湾区口腔联盟委员会常务委员,广东省整形美容协会青年学术委员会委员。2021年完成南方医科大学博士后工作,发表SCI论文46篇。其中以通讯或第一(含共一)作者身份发表SCI收录文章19篇。主持国家自然科学基金、广东省自然科学基金及中国博士面上基金等多项课题。申请国家发明专利5项,1项完成转化。曾获得广东医学科技奖(2019)、中国整形美容协会科学技术奖创新奖(2017)及广东省科学技术进步奖二等奖(2016)。临床擅长“冠根一体化”治疗,显微根管治疗,美学树脂、嵌体修复等。



【通信作者简介】 孙书昱,主任医师,博士,南方医科大学口腔医院牙体牙髓病科副主任。兼任中华口腔医学会牙体牙髓病学专业委员会委员,中华口腔医学会老年口腔医学专业委员会委员,广东省口腔医学会牙体牙髓病学专业委员会常务委员,广东省住院医师规范化培训临床带教教师。从事牙体牙髓疾病的防治及诊疗工作多年,在龋病、牙髓病以及根尖周病的诊疗,疑难病例的评估、治疗以及预后判断,患牙保存的评估,微创牙体修复、根管治疗等方面有丰富的临床经验,较早在本专业开展现代根管治疗、牙体美学修复及数字化牙体修复技术。