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·专家论坛·

根管峡区的定位、发生率及临床意义

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【摘要】 根管峡区（root canal isthmus，RCI）是位于同一牙根内、根管之间含有牙髓或牙髓衍生组织，呈现为带状狭窄的连接或含有交通支及横向吻合的解剖学结构，它常存在于含有两个根管的牙根中，解剖结构复杂。不同牙位的RCI发生率不尽相同，发生率最高的部位是下颌第一磨牙近中根和上颌第一磨牙近中颊根。RCI的存在增加了根管治疗的难度，并给患牙治疗带来了预后的不确定性。临床上，对于可能存在RCI的患牙建议使用锥形束CT及牙科显微镜进行识别；同时，对含RCI患牙治疗时应考虑选择合适的器械以及超声辅助下加强根管冲洗，有助于提高根管治疗以及根尖手术的成功率。目前的技术对于RCI的清理和充填仍存在一定的局限性，相应技术设备的研发改进是目前的研究热点，也是未来的研究方向。

【关键词】 根管峡区；　根管解剖；　根管预备；　根管充填；　根管冲洗；　恒磨牙；　锥形束计算机断层扫描
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Location, incidence and clinical implications of the root canal isthmus

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【Abstract】 Root canal isthmus(RCI) is defined as a narrow, ribbon-shaped communication between two root canals that contains pulp or tissue derived from pulp. Any root that contains two or more root canals has the potential to contain an isthmus. The incidence of RCI from different tooth positions varies, with the highest RCI incidences usually found in the mesial root of the mandibular first molar and the mesiobuccal root of the maxillary first molar. The presence of RCI increases the difficulty of root canal therapy and introduces uncertainty regarding the prognosis for dental treatment. It is recommended to use CBCT and dental microscopy to identify teeth with suspected RCI in clinical practice. At the same time, for treatment of teeth with RCI, appropriate instruments should be selected, and enhanced root canal irrigation assisted by ultrasound should be considered to improve the success rate of root canal treatment and endodontic root-end surgery. The current technology still has some limitations regarding the cleaning and filling of RCI and additional research and development. Improvement of the corresponding technology and equipment is a current research

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hotspot and a future research direction.

【**Key words**】 root canal isthmus; root canal anatomy; root canal preparation; root canal filling; root canal irrigation; permanent molar; cone-beam computed tomography

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根管峡区(root canal isthmus,RCI)是解剖学上位于同一牙根内、根管之间含有牙髓或牙髓衍生组织,呈现为带状狭窄的连接或含有交通支及横向吻合的结构[1-2]。研究者对上、下颌第一磨牙近中颊根及近中根的解剖形态进行研究,发现RCI在此类扁根的发生率较高,特别是在根尖3~5 mm处[3]。任何含有双根管的牙根都可能存在RCI,1997年,Hsu和Kim[4]提出了RCI的分类法,具体如下:①Ⅰ型:2或3根管之间无交通(two or three canals with no communications);②Ⅱ型:2根管之间有一条明确的连接(two canals with a definite connection between them);③Ⅲ型:3根管之间有一条明确的连接(three canals with a definite connection between them);④Ⅳ型:根管向根管峡区延伸(canals extend into the isthmus area);⑤Ⅴ型:整个切面均可见完全连接(a true connection or corridor throughout the section)。目前,将根管峡区分为完全性峡区(complete isthmus)和部分性峡区(partial isthmus)比较多见,完全性峡区指存在于两条主根管之间的完全连续的连接,而部分峡区是指在两条主根管之间有一处或多处的不完全连接。这种解剖学特点决定了RCI在感染根管中可能成为细菌的贮存池,对于根管清理、根管充填和根尖外科手术都提出了极大的挑战,RCI的存在与否直接影响临床治疗的策略和治疗效果[5],因此,熟悉掌握RCI的定位和发生率,对于临床治疗有着重要的指导意义。

1　RCI的定位和发生率

临床上,RCI的定位主要依赖于牙科显微镜与锥形束CT(cone beam CT,CBCT)影像资料,离体牙则一般通过切片观察或micro CT的方法进行研究。Pécora等[6]采用CBCT动态检测RCI,按照从根管口至根尖方向进行读片记录,对RCI的定位和深度进行分类:①起止均位于颈部1/3;②起于颈部1/3,止于根中1/3;③起于颈部1/3,止于根尖1/3;④起止均位于根中1/3;⑤起于根中1/3,止于根尖1/3;⑥起止均位于根尖1/3;⑦无RCI;发现RCI在磨牙的发生率较高,而且起止点在上述各组中均有存在。Estrela等[7]对1 400颗恒牙进行CBCT分析,结果显示RCI可存在于除上颌前牙以外的任何其他牙位,其中下颌第一磨牙发生率最高,为87.9%,下颌第二磨牙、上颌第一磨牙和第二磨牙RCI发生率分别为66.3%、60.8%、46.5%,上颌第二前磨牙和下颌侧切牙也具有较高的RCI发生率,分别为50.5%、47.6%。年龄越高,RCI发生率越低。Pécora等[6]对200颗恒磨牙的CBCT数据进行分析,指出RCI发生率均在70%以上。Haghanifar等[8]对1 654颗牙齿(包括809颗上颌牙和845颗下颌牙)的CBCT资料进行回顾性分析,发现恒牙存在完全RCI的发生率为8.6%,最常见于下颌第一磨牙近中根,其次为上颌第一磨牙近中颊根,尖牙和中切牙未见RCI。下颌中,RCI发生率最低的牙位是第二前磨牙。上颌中,RCI起始均位于根中1/3的发生率最高,而下颌中,RCI起于根尖或根中1/3,至于根尖1/3的发生率最高。蒙古人种中,年龄0~20岁的RCI发生率较高,推测可能是继发性牙本质的沉积,随着年龄增大,RCI发生率逐渐降低[9]。

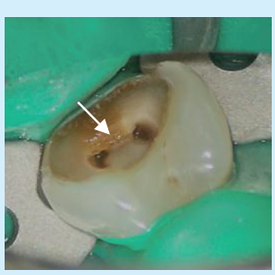
1.1　恒切牙RCI

恒切牙一般为单根管,但近年来许多研究显示下颌恒切牙有时会存在双根管和RCI,提示患牙根管治疗前,应考虑患牙存在双根管的可能。国内学者对20颗下颌恒切牙进行切片分析显示,根管唇舌径明显大于近远中径,该牙双根管率以根中1/3最高,依次为根冠1/3和根尖1/3,根管的冠1/3、中1/3和根尖1/3处RCI的发生率分别为62.5%、75.0%和48.7%,以Ⅳ型最多,Ⅴ型次之[10]。国内学者对33颗下颌恒切牙进行micro-CT分析发现,距离根尖3~6 mm处具有较高的RCI发生率,多位于距离根尖5 mm处(85.5%),完全RCI的发生率(49.7%)远远高于部分RCI(4.5%),最薄根管壁厚度不到0.5 mm[11]。

1.2　恒前磨牙RCI

上颌第一前磨牙多数是双根管,但是有研究报道上颌第一前磨牙单个牙根内存在双或多根管

的比例接近30%，而上颌第二前磨牙则接近41%[12]，提示上颌前磨牙存在RCI的比例较高。而下颌前磨牙多数为单根，有时会存在多根管。国内学者报道，存在多根管的下颌第一前磨牙，多含有根面凹陷沟，根管形态复杂，RCI发生概率为40.62%，大部分位于根中1/3及根尖1/3[13]（图1）。在约旦、土耳其、美国人群中，上颌第一前磨牙RCI发生率分别为7%、12～17.6%、34.2%[14]。Jayasimha等[15]对200颗印度人上颌第二前磨牙进行切片分析，显示RCI发生率为19%。Ahmad等[16]指出上颌第一前磨牙RCI发生率为16%。研究发现，在对侧同名前磨牙中RCI完全对称的发生率较低[17]。



Arrow show the root canal isthmus

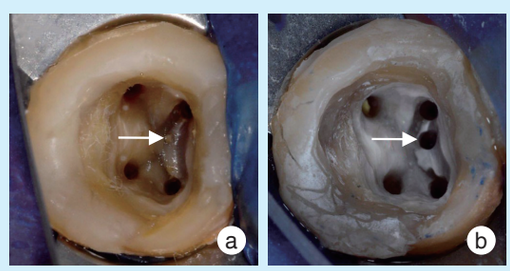
Figure 1　Root canal isthmus of the mandibular first molar

图1　下颌第一前磨牙根管峡区

1.3　恒磨牙RCI

Lima等[18]对128颗上下颌第一、第二磨牙进行切片观察，结果显示在扁平牙根的牙齿中RCI非常常见，RCI发生率最高的部位位于距离根尖7 mm处（下颌磨牙远中根为距离根尖5.5 mm处），完全性峡区（V型）比较常见（28.8%），在下颌第一磨牙和第二磨牙近中根IV型峡区发生率较高（分别为36%和23.9%）。也有学者对包含18 781颗下颌第一磨牙的41篇文献进行回顾，发现54.8%的下颌第一磨牙近中根和20.2%的远中根都存在管间峡区[19]。年龄越小，近中颊根管口-近中舌根管口根管距离越小，RCI发生率越高[9]。

韩国学者发现只要上颌第一磨牙的近中颊根或下颌第一磨牙的近中根存在2个主根管，RCI的发生概率就会增加，距离根尖3 mm处，RCI与上颌磨牙近中颊根或者下颌磨牙近中根的远中面之间的平均牙本质厚度均小于1 mm。也有研究发现上颌磨牙的近中颊根距离根尖3.6 mm处RCI最为明显[20]，上颌第一磨牙近中颊根距离根尖8～11 mm处以及上颌第二磨牙近中颊根距离根尖9.5～11 mm处的远中壁比近中壁薄约1/3，此提醒医师在对相应区域进行根管预备时应提防根管壁的过度切削[18]，也提示根尖切除术和根尖倒充填术应考虑RCI这些相关的解剖学数据。同时，由于RCI的存在，细小根管口和RCI的位置一旦有重叠，极易造成遗漏根管。因此，临床医师在根管治疗时也应仔细甄别RCI处是否有根管口的存在（图2）。



a: arrow show the root canal isthmus before the missed root canal preparation; b: arrow show the missed root canal after the missed root canal preparation

Figure 2　Root canal isthmus from the maxillary molar and missed root canal orifice

图2　上颌磨牙近中颊根根管峡区与遗漏根管口

有研究对峡区终止于根尖1/3的下颌第一磨牙近中根进行定量定性分析，发现带状峡区内解剖结构复杂，如RCI的底壁位于根尖1/3区，则RCI顶直径显著大于峡区底部；而在圆度（roundness）方面，RCI顶壁和底壁之间没有显著差异[21]。有研究[22]对缅甸人Vertucci's IV型的下颌第一磨牙近中根进行micro-CT分析发现，侧支根管和多根尖孔的发生率较高，RCI同近中颊侧根管、近中舌侧根管具有相同的根管侧枝发生率，RCI在距离根尖2～6 mm处发生率显著高于距离根尖0～2 mm处。有研究者发现下颌第一磨牙的近中颊根管和近中舌根管之间如果存在RCI，近中中间根管（middle mesial canal，MMC）的概率会增大5倍，因此下颌第一磨牙的近中颊侧根管和近中舌侧根管之间如果存在RCI，需要仔细甄别是否存在真性MMC[23-24]。

关于RCI的另一个重要的解剖形态是C形根管，Cooke和Cox于1979年首先报道了下颌第二磨牙、下颌第三磨牙的C形根管形态[25]，发现此类根管横断面呈现为C形的带状连接，RCI的形态较为复杂。C型根管在亚洲人群的发生率远远高于欧美人群，在上、下颌磨牙，下颌第一前磨牙，上颌侧切牙等牙位均可发生，但最多见的为下颌第二磨

牙[26]，有研究显示C形根管治疗失败最常见的原因是微渗漏(45.2%)，其次是RCI(23.8%)[27]。国内学者对中国人58颗融合单根的下颌第二磨牙进行micro-CT扫描发现，54颗牙齿呈现C形根管形态，根管口常位于釉牙骨质界根方3 mm处，根管横断面形态从根管冠方向根尖区延伸过程中变化极大，无论对根管口的定位还是对根管的清理都存在较大的困难[28]。总体而言，RCI发生率最高的牙位是下颌第一磨牙近中根(表1)，其次是上颌第一磨牙近中颊根(表2)，其余牙位RCI发生率不尽相同，这可能和研究人群的种族、研究方法、样本数量等因素密切相关。

表1　下颌第一磨牙近中根根管峡区发生率

Table 1　Incidence of mesiobuccal root canal isthmus in mandibular first molar

Nationality	Sample number	Method	Prevalence (%)	Year of publication	Note
South Korea	31	Section observation	100	2020[29]	The value was measured 3mm from the root tip
China	823	CBCT	64.6	2019[9]	Mongoloid population
Brazil	140	Micro-CT	74.3	2019[32]	The proportion of Type I-V was 52.9%,7.7%,2.9%,19.2% and 17.3% from the Hsu & Kim's classification
Iran	150	X-ray and Stereomicroscope	44.6	2017[33]	The RCI prevalence of distal roots was 27.3%
USA	122	CBCT	64.7	2017[24]	Mandibular second molars got a higher RCI prevalence without statistically difference
Brazil	132	CBCT	87.9	2015[7]	
India	150	Section observation	30	2012[34]	The RCI prevalence of distal roots was 10
China	36	Micro-CT	49.5-66.1	2009[35]	The value was observed 0-6 mm from the root tip, the highest RCI prevalence occurred in 4-6 mm from the root tip The RCI prevalence of distal roots was 17.3%-17.8%
UK	20	Micro-CT	17.25-50.25	2005[36]	The value was observed 3-5 mm from the root tip, the highest RCI prevalence occurred in 3 mm from the root tip
Poland	50	Section observation	20	2004[37]	The value was observed 3 mm from the root tip. The RCI prevalence of mandibular second molar was 18%
Brazil	50	Section observation	59	2003[3]	The value was observed 0-6 mm from the root tip, the highest RCI prevalence occurred in 3-5 mm from the root tip

RCI: root canal isthmus; CBCT: cone beam CT

表2　上颌第一磨牙近中颊根根管峡区发生率

Table 2　Incidence of mesiobuccal root canal isthmus in maxillary first molar

Nationality	Sample number	Method	Prevalence (%)	Year of publication	Note
South Korea	28	Section observation	89.3	2020[18]	The value was measured 3mm from the root tip
China	494	CBCT	92.5	2019[30]	Investigated from a 9 to 12 years old population
Brazil	102	CBCT	60.8	2015[7]	
Brazil	50	Section observation	29	2003[3]	The value was observed 0-6 mm from the root tip, the highest RCI prevalence occurred in 3-5 mm from the root tip
Canada	50	Section observation	62.5	2002[31]	
USA	50	Section observation	100	1995[2]	The value was observed 0-6 mm from the root tip, the highest RCI prevalence occurred in 4 mm from the root tip

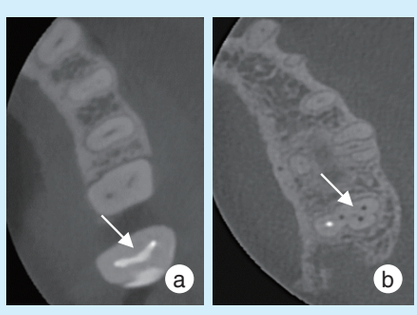
RCI: root canal isthmus; CBCT: cone beam CT

2　RCI的临床意义

2.1　存在RCI患牙根管治疗时辅助检查的必要性

由于RCI对根尖手术疗效的影响，较早就被很多学者所关注，1984年Vertucci指出RCI是根管间的吻合，而有学者认为RCI是根管之间包含有牙髓组织的带状连接，它的存在对患牙根管的清理和严密封闭都提出了巨大的挑战，据报道，23.8%的下颌第二磨牙C型根管治疗失败的原因是RCI[27]。在扁根或锥形牙根内存在RCI的概率较大，而根管开口常位于根管峡区内、在往根尖向走

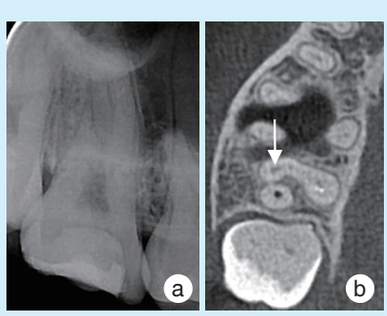
行过程中变异较大(图3),肉眼下观察不清,容易遗漏根管。传统的根尖X线片在显示复杂的根管系统时因只能提供二维影像,具有较大局限性,可能出现图像重叠或失真,小视野CBCT对于峡区内根管形态的辨认有一定帮助(图4)。然而根尖区RCI对检测设备的分辨率要求较高,即便是小视野CBCT也不能准确检测根尖RCI,对根尖复杂根管形态的判断也不可靠[38]。也有研究发现根管预备后,RCI的三维结构会发生改变,CBCT可用于评估根管预备前后RCI的结构差异[39]。此外,CBCT对峡区内根管的分布和走形有着精准的判断,尽管在观察精确度方面存在争议,但CBCT仍是目前应用最为广泛,观察、重建复杂根管系统的常用影像学检测手段。



a: RCI morphology of the upper part from the cross section of the CBCT image (arrow show); b: RCI morphology of the lower part from the cross section of the CBCT image (arrow show); RCI: root canal isthmus; CBCT: cone beam CT

Figure 3　The difference between the upper part and the lower part of the root canal isthmus from maxillary second molar

图3　上颌第二磨牙根管峡区根管上下段的差异



a: X-ray can not show clear morphology of the root canal system; b: CBCT clearly shows the band-area of the fused roots (arrow show); RCI: root canal isthmus; CBCT: cone beam CT

Figure 4　The effect of root canal isthmus detection via different methods

图4　不同检测手段对根管峡区检出的影响

2.2　RCI对根管预备和冲洗效果的影响

研究报道同一名医师对721颗牙齿进行根管治疗,采用逐步后退法结合预弯超声锉ultrasonic files进行根管预备,统计显示RCI的存在对治疗结果并没有显著影响[40]。但大部分文献报道RCI的存在对根管治疗的效果具有明显影响。尽管进行持续根管冲洗,下颌磨牙近中根进行旋转器械根管预备过程中及预备后,仍会在RCI堆积许多牙本质碎屑,这些碎屑可能会对RCI后续的根管充填造成不良影响[41]。虽然适当扩大下颌第一磨牙的根尖孔大小可显著减少根管系统内碎屑,但对于近中根的RCI而言,仍然是清洁盲区[42]。

朱丽娜等[39]对66颗单根双根管的上颌第一前磨牙进行CBCT分析,发现在距离根尖0~6 mm处,根管预备前后每1 mm切面的RCI发生率均有差异,其中距离根尖1 mm处差异最低,而距离根尖6 mm处最高。部分RCI的发生率显著高于完全RCI的发生率。根管预备后,距离根尖0~6 mm的RCI发生率显著下降,但完全RCI的发生率显著增加。说明根管机械预备可能改变RCI类型,但却无法完全消除RCI的存在及其对根管治疗的不良影响。因此,对于如何彻底清理含RCI根管中的牙本质碎屑和细菌,学界进行了大量的研究。

2.2.1　预备器械的比较　由于RCI的形态是不规则的,因此常规根管预备锉无法接触到RCI的所有壁,和ProTaper系统相比,采用带有冲洗装置的自适应锉SAF系统进行根管预备可显著减少RCI的牙本质碎屑(accumulated hard-tissue debris, AHTD)残留[43]。此外有研究报道与往复旋转预备方式相比,连续旋转预备对峡区内碎屑的清理效果较好[44]。

2.2.2　新型根管冲洗系统　研究显示目前所有的根管预备系统都不能与根管壁完全接触,根管冲洗作为根管机械预备的补充,可将抗菌冲洗液带入根管系统中,但无法驱动冲洗液完全到达RCI[45]。对于含RCI的复杂根管系统,其清洁效率取决于冲洗液的及时补充、气锁现象(vapor lock)控制和冲洗液的超声激活效率等相关变量[46]。近年来不断研发出新型的根管冲洗系统,以增强冲洗系统输送冲洗液的能力。通常以下颌第一磨牙近中根RCI内牙本质碎屑的清除能力作为冲洗效果的衡量标准。如间断超声冲洗装置(intermittent ultrasonic, IU)(Irrisafe, Satelec, Bordeaux, 法国),连续超声冲洗装置(continuous ultrasonic, CU)(ProUltraPiezoFlow, Dentsply Maillefer)和多声波系统

(GentleWave system, GW)(Sonendo Inc, Laguna Hills,加拿大)三种系统,其去除牙本质碎屑效率介于80.0%~97.9%,和CU相比,GW去除效果较优,CU和IU效果相仿[47];对比超声冲洗(ultrasonically activated irrigation, UAI)、光子诱导光声流激光荡洗(photon-induced photoacoustic streaming, PIPS)和冲击波增强发射光声流装置(shock wave enhanced emission photoacoustic streaming, SWEEPS)三种系统,SWEEPS系统清除率碎屑为84.3%,显著高于另外两种系统,但三种系统均无法将根管系统中的AHTD彻底清除[48];在另外四种终末根管冲洗系统对比研究中,被动超声冲洗(passive ultrasonic irrigation, PUI)、EndoVac(一种根尖负压冲洗系统)、Self-Adjusting File(SAF)和EasyClean进行对比,其去除下颌磨牙牙本质碎屑的效率相似,但都不能完全去除AHTD[49-51]。所有的新型冲洗系统较传统冲洗方式清洁RCI的效率明显提高,但均无法实现RCI处的完全清洁。2016年印度学者研究了新型根管冲洗系统,通过连续加热冲洗液的根尖负压冲洗释放装置来加强冲洗效率(EndoIrrigator Plus, Innovations Endo, Nasik,印度),组织学分析发现,尽管新系统的清洁效率较传统注射器冲洗及被动超声冲洗明显改善,但仍无法完全清除RCI的残留牙髓组织[52]。

除了去除含RCI根管的牙本质碎屑,根管冲洗对去除根管峡区内的$Ca(OH)_2$封药也是研究模型之一。研究报道,与EndoActivator和注射器冲洗相比,采用PIPS和超声荡洗可更有效地去除根管系统和RCI内的$Ca(OH)_2$[53]。超声和激光辅助冲洗是否有助于提高含RCI根管的牙本质碎屑清理效果尚有争议。有研究报道在对去除含RCI的下颌第一磨牙近中根管的牙本质碎屑时,声波或超声辅助的根管荡洗效果并不优于普通手动冲洗[49]。也有研究显示超声辅助和激光辅助对清除下颌磨牙近中根RCI牙本质碎屑效果相仿,清理效果显著优于传统手动冲洗,但都不能彻底清除牙本质碎屑[54-55]。因此对于RCI等根管不规则区域而言,根管冲洗较为重要,目前的预备和冲洗技术均无法完全去除根管预备产生的牙本质碎屑,实现根管系统彻底的清洁。

2.2.3　根管冲洗时针头放置的位置　目前临床多是采用注射器冲洗方式,根管冲洗时针头放置的位置对冲洗效果可能有影响,对于存在RCI的下颌磨牙,根管冲洗针头插入放置的深度显著影响牙本质碎屑的清除效率,冲洗针尖放置在距工作长度1 mm处和放置在距工作长度5 mm处相比,冲洗效率提高了3倍[56]。但在水凝胶模拟生物膜的RCI模型中,激光辅助的根管荡洗效果显著优于声波及超声辅助的根管荡洗,且荡洗的效果与冲洗尖放置在根管内的深度无关[57]。

2.2.4　不同冲洗液对RCI内生物膜的清理　冲洗液成分对根管内生物膜的清除起着重要的作用,在RCI内的生物膜较根管壁的生物膜更难以清除,尽管有报道一些抗微生物多肽能辅助对包括RCI在内的根管各个难以预备的部位的杀菌,在整体满意率及操作性方面仍需要大量研究和实践[58]。研究报道高浓度次氯酸钠溶液(6.0%)对于RCI内粪肠球菌生物膜清除效果较好[59]。

2.3　RCI对根管充填的影响

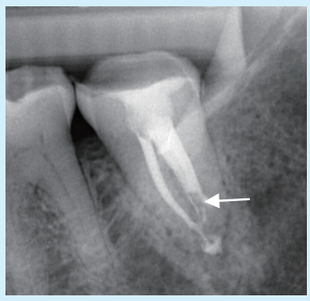
RCI是不规则区,对存在RCI的根管充填时,热牙胶垂直加压技术和超声辅助的根充效果均优于手动侧方加压充填,但是三种方法均不能完全消灭死腔[60]。有学者对比了热牙胶垂直加压充填法和单尖法对存在RCI的下颌第一磨牙根充效果,显示两种充填方法在峡区内的空隙率无显著差异,均无法达到对根管腔的彻底封闭[61](图5)。从力学角度看,连接双根管的RCI可视为牙根内天然的薄弱平面或裂隙,有研究显示与无RCI的牙根相比,根管充填时有RCI的牙根导致牙根纵裂的最大力可从50 N下降至10 N,因此下颌磨牙含有双根管的近中根较单根管的远中根更易发生牙根纵裂(vertical root fracture, VRF),提示在含有RCI的牙根进行牙胶加压时应减小加压力度[62]。此外在RCI内放置根管桩亦应谨慎。以上研究提示含RCI患牙的根管治疗中,根管的合理预备、彻底消毒和充填方法选择的重要性。

2.4　RCI对根管治疗复诊频率的影响

根管治疗诊间封$Ca(OH)_2$和一次性根管治疗相比,可以显著改善根管系统微生物状态。一次性根管治疗患牙的根分叉、RCI和牙本质小管中的残余细菌更为丰富和常见,因此诊间封药对根充前根管系统的细菌控制是必要的[63]。提示对于含有RCI的患牙,应尽量行诊间封药,将包含RCI在内的根管内细菌量控制在合理范围内,有助于提高患牙的治疗成功率。

3　小　结

RCI是位于牙根内连接双根管或多根管的带



arrow indicates the RCI root filling missed space; RCI: root canal isthmus

Figure 5　The root canal isthmus root filling missed space of the C-shaped root canal system from mandibular molar

图5　下颌磨牙C形根管根尖段根管峡区充填空隙

状通路,除上颌前牙外,在所有牙位都可能发生,其形态不规则,临床容易出现根管治疗不彻底,根尖封闭不严密等现象,提示治疗前对于含有RCI的患牙,如果X线片根管影像不清晰,需要拍小视野CBCT检查,对RCI准确定位,熟悉其形态。此外对含有RCI的牙根,根管治疗应在手术显微镜下进行,借助优越的照明和放大效果可更加清楚地观察RCI及其内部的结构[64],峡区内可能存在多个根管口,对峡区应仔细探查防止遗漏根管。由于RCI在牙根的冠方、根中段、根尖区均可能发生,其存在与否直接影响临床治疗的策略和治疗效果[41],考虑到根管预备后牙根受损的风险,对于含RCI的患牙行根管治疗时应考虑选择合适的器械以及超声辅助下进行大量根管冲洗。目前的技术对于RCI的清理和充填仍存在一定的局限性,应加强对技术设备的改进。

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