

[DOI]10.12016/j.issn.2096-1456.2023.07.006

· 临床研究 ·

四种方法去除根管内氢氧化钙的效率比较

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【摘要】 目的 比较四种清除根管内氢氧化钙方法的效率,为临床根管内消毒药物的去除提供参考。方法 收集65颗离体下颌单根管前磨牙,截冠、根管预备后,随机选取1颗做空白对照组,剩余64颗平均分A、B组($n=32$),A组注入成品水溶性氢氧化钙,B组注入成品油溶性氢氧化钙。封药2周后,A、B组内根据不同冲洗技术随机分为4组($n=8$),分别为侧方开口注射器冲洗组、声波荡洗组、超声荡洗组、Er:YAG激光荡洗组。锥形束CT扫描氢氧化钙清除前后的样本,将数据导入Mimics软件进行三维重建,将根管分为根上段、根中段和根尖段,并计算根管各段的氢氧化钙体积。清除前氢氧化钙体积为 V_1 ,清除后氢氧化钙体积为 V_2 ,清除率 $= (V_1 - V_2) / V_1 \times 100\%$ 。使用三因素方差分析进行统计分析。A、B组重建后选择根尖残余氢氧化钙量较多的各1颗与空白对照行扫描电镜(SEM)观察。**结果** 两种类型的氢氧化钙用4种冲洗方式均无法完全去除氢氧化钙。水溶性氢氧化钙清除率比油溶性氢氧化钙高($P < 0.001$);根管三段中,根尖段的清除率较低($P < 0.05$)。Er:YAG激光荡洗组在去除两种氢氧化钙的效率最高,尤其在根尖段;超声组对比声波荡洗组与注射器冲洗组,均有显著优势($P < 0.05$),声波荡洗组仅在油性氢氧化钙根中段组清除率高于注射器冲洗组($P < 0.05$)。扫描电镜观察,两种氢氧化钙均无法完全去除,但油溶性的氢氧化钙残存率大。**结论** 四种清除方式中,两种类型的氢氧化钙均无法完全去除,油溶性较水溶性氢氧化钙难去除;Er:YAG激光荡洗较其他冲洗方式,清除效率较高。

【关键词】 氢氧化钙; 根管冲洗; Er:YAG激光荡洗; 超声荡洗; 声波荡洗; Mimics软件

【中图分类号】 R78 **【文献标志码】** A **【文章编号】** 2096-1456(2023)07-0494-07

【引用著录格式】 杨楠,王月月,单晓阳,等.四种方法去除根管内氢氧化钙的效率比较[J].口腔疾病防治,2023,31(7):494-500. doi:10.12016/j.issn.2096-1456.2023.07.006.

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【Abstract】 Objective To compare the efficiency of four methods that remove calcium hydroxide in root canals and to guide clinical practice. **Methods** Sixty-five isolated mandibular single root canal premolars were collected. After crown cutting and root canal preparation, a tooth was randomly selected as the blank control group, and the remaining 64 teeth were equally divided into Groups A and B ($n=32$). Group A was injected with water-soluble calcium hydroxide, and Group B was injected with oil-soluble calcium hydroxide. After 2 weeks of drug sealing, Groups A and B were randomly divided into 4 groups ($n=8$), including the lateral opening syringe group, sonic vibration group, ultrasonic group, and Er:YAG laser group. Before and after calcium hydroxide removal, the samples were scanned by cone-beam CT, and the data were imported into Mimics for 3D reconstruction. The root canal was divided into the following segments: superior root segment, middle and apical, and the calcium hydroxide volume of each segment of the root canal was calculated. The volumes of calcium hydroxide before and after removal were V_1 and V_2 , respectively, with a clearance rate $= (V_1 - V_2) / V_1 \times 100\%$. Three-factor ANOVA was used for statistical analysis. After Groups A and B were recon-

【收稿日期】 2022-10-19; **【修回日期】** 2023-01-09

【基金项目】 青岛市医药卫生科研计划项目(2021-WJZD167)

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structed, the apical region with residual calcium hydroxide was selected, and the blank control was observed by scanning electron microscopy (SEM). **Results** Two types of calcium hydroxide could not be completely removed by the four flushing methods. The clearance rate of water-soluble calcium hydroxide was higher than that of oil-soluble calcium hydroxide ($P < 0.001$). Among the three segments of the root canal, the clearance rate of the apical segment was lower ($P < 0.05$). The Er: YAG laser treatment group showed the highest removal efficiency of two kinds of calcium hydroxide, which was higher than that of the other groups, especially in apical of the root. Compared with the sonic wave washing group and the syringe washing group, the ultrasonic wave washing group exhibited significant advantages ($P < 0.05$). The clearance rate of the sonic wave washing group was higher in the oily calcium hydroxide root middle group than in the syringe washing group ($P < 0.05$). SEM showed that the two kinds of calcium hydroxide could not be completely removed, but the residual rate of oil-soluble calcium hydroxide was large. **Conclusion** Both types of calcium hydroxide could not be completely removed, and compared to water-soluble calcium hydroxide, oil-soluble calcium hydroxide was more difficult to remove. Among the four cleaning methods, Er:YAG laser swing washing showed the higher cleaning efficiency.

【Key words】 calciumhydroxide; root canal irrigation; Er: YAG laser cleaning; ultrasonic cleaning; sonic vibration; Mimics software

J Prev Treat Stomatol Dis, 2023, 31(7): 494-500.

【Competing interests】 The authors declare no competing interests.

This study was supported by the grants from Qingdao Medical and Health Research Program (No. 2021-WJZD167).

根管内封药为根管消毒常用的方法之一^[1],氢氧化钙作为最常见的根管消毒药物被广泛应用。不同赋形剂下的氢氧化钙的根管消毒效率不同^[2],清除的方法和效率也不同。有研究称,任何清除方法均会残留氢氧化钙,且主要残留于根尖、侧支根管及根管弯曲等部位^[3]。残存于根管的氢氧化钙会影响根管充填时的根尖封闭效果^[4]。因此探讨如何去净根管内残留氢氧化钙成为近两年国内研究热点。临床上常规使用注射器冲洗、超声根管荡洗、声波根管荡洗等方法,而Er: YAG激光活化荡洗成为近期研究的热点^[5]。Er: YAG激光是一种固体脉冲激光,其波长为2 940 nm,恰好位于水的最高吸收峰值,能被水和羟基磷灰石高度吸收而产生相应的光热作用,产生更微弱的热损伤,更高的安全性^[6]。本研究旨在探讨何种方法清除氢氧化钙效率较高,为临床操作提供参考。

1 材料和方法

1.1 主要仪器与材料

5 mL侧方冲洗器(配针0.4冲洗器,米筛浪,中国);Endodontic Activator(微笑美齿,中国);超声仪器(P5 NewtroXS, Satelec, 法国);Er: YAG激光仪(Fotona Light Walker, Fotona Lasers, 斯洛文尼亚);根管显微镜(EXTARO300FS, ZEISS, 德国);慢速切锯(Buehler, 美国);机用镍钛锉(欧罗德卡, 中国);根管马达(Motopex, 啄木鸟, 中国);锥形束CT

(cone beam CT, CBCT)(CS 9300, 锐柯, 美国);油性氢氧化钙(vitapex, 森田, 日本);水溶性氢氧化钙(派丽登, 美国);1%次氯酸钠(朗力, 中国);17% EDTA冲洗液(朗力, 中国);生理盐水(威高, 中国)。

1.2 样本选择

收集65颗下颌单根管恒前磨牙,拍摄CBCT确认根尖发育完全、根管弯曲不超过 10° ,无龋坏、无裂纹、无钙化、牙根无内外吸收、未行牙髓治疗。清除牙齿表面的牙周膜及牙结石后,放入生理盐水中备用。本研究已经青岛大学附属医院伦理委员会批准(QYFYWZLL27474)。

1.3 研究方法

1.3.1 根管预备 65颗牙齿在距根尖16 mm处截冠,疏通根管后,并以10号K锉尖端与根尖孔平齐的长度-1 mm作为工作长度(均为15 mm),机用镍钛锉预备根管至35号06锥度。

1.3.2 分组与处理 随机选取1颗作为空白对照组,剩余64颗随机分为两组($n = 32$),分别注入水溶性氢氧化钙和油性氢氧化钙,玻璃离子水门汀封闭根管口,硬蜡封闭根尖孔。对两组样本进行CBCT扫描,将牙齿DICOM数据导入Mimics软件进行冲洗前的三维重建,以5 mm分界^[7],将根管分为根上段、根中段及根尖段,重建并计算各个区域的氢氧化钙的体积(V_1)确认氢氧化钙充满根管。将离体牙放置于 37°C 恒温水浴锅中静置14 d。

将注入不同类型氢氧化钙的离体牙分别随机

分为4个亚组($n = 8$),以不同冲洗方法去除不同类型的氢氧化钙。冲洗前使用35号K锉疏通根管到达工作长度,手动预备30 s,疏通根管。冲洗液均为3 mL NaClO溶液,3 mL EDTA溶液交替冲洗,3 mL生理盐水终末冲洗。

注射器冲洗组(SYIG):侧方开口的5 mL注射器到达距离根尖2 mm处,间断冲洗60 s。

声波荡洗组(SOIG):Endodontic Activator(35号04锥度工作尖,10 000 rpm)到达距离根尖2 mm处,荡洗20 s,保证根管内足量冲洗液,重复3个循环。

超声荡洗组(ULIG):超声工作尖(25号)达到距离根尖2 mm处(赛特力,档位4)荡洗20 s,保证根管内足量冲洗液,重复3个循环。

激光荡洗组(LAIG):Er:YAG激光,工作模式(20 mJ,15 Hz,0.3 W,SSP模式)工作尖放置于根管口处荡洗,以20 s为一循环,保证根管内足量冲洗液,共进行3个循环荡洗。

冲洗结束后,重复CT扫描及Mimics三维重建,测量并计算根管各段残留的氢氧化钙的体积(V_2)。计算冲洗前、后水溶性氢氧化钙和油溶性氢氧化钙体积差 V_1-V_2 ,清除率 $= (V_1-V_2)/V_1 \times 100\%$ 。

1.3.3 扫描电镜观察不同类型氢氧化钙的残余
Mimics重建后选取根尖残余不同类型氢氧化钙较多的各1颗牙,及空白对照组1颗牙,劈牙后,选择根尖段残留较多药物部位观察。

1.4 统计学分析

采用SPSS 26.0软件处理数据,因各组数据均

符合正态性($P > 0.05$),使用三因素方差分析, $P < 0.05$ 为差异有统计学意义。

2 结果

2.1 不同冲洗方式下两种氢氧化钙的残余量

使用Mimics软件对两种氢氧化钙冲洗前后的CT影像进行三维重建。结果显示,油溶性氢氧化钙的残余量较水溶性氢氧化钙多。Er:YAG激光荡洗效率更高。药物更容易残留于根尖段(图1)。

对各组冲洗前后的氢氧化钙的体积进行单因素方差分析,冲洗前根管各段的氢氧化钙体积差异均无统计学意义($P > 0.05$),表示样本一致性,冲洗后各组间的剩余体积间差异均有统计学意义($P < 0.001$)(表1)。

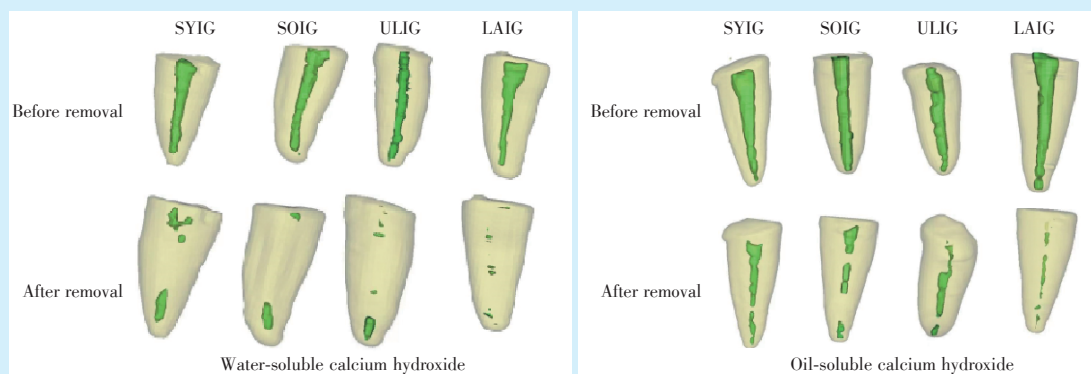
2.2 根管内不同类型氢氧化钙残留的形态

SEM下观察可见,空白对照组可见明显的牙本质小管(图2a);水溶性氢氧化钙组虽然残余的氢氧化钙封闭牙本质小管,有较多牙本质小管开放(图2b);油溶性氢氧化钙组的氢氧化钙残余根管较为均匀,但牙本质小管开放较少(图2c)。

2.3 分析三种因素对氢氧化钙清除率的影响

三因素析因设计的方差分析结果示:三因素中冲洗方式、根管内消毒药物及根管的位置均对根管内氢氧化钙清除率有显著影响($P < 0.001$)。其中三者之间无明显交互作用($P > 0.05$),根管分段与其余两者之间各有交互作用($P > 0.05$)(表2)。

单独分析各因素之间的差异:4种冲洗方式均无法完全去除根管内水溶性及油溶性氢氧化



SYIG: syringe irrigation group; SOIG: sonic irrigation group; ULIG: ultrasonic irrigation group; LAIG: laser-activated irrigation group. The residual amount of oil-soluble calcium hydroxide was more than that of water-soluble calcium hydroxide. PIIG group has the best cleaning effect. Calcium hydroxide were more likely to remain at 1/3 of the root apical

Figure 1 Three-dimensional reconstruction of water-soluble calcium hydroxide or oil-soluble calcium hydroxide removal from root canals by different flushing methods

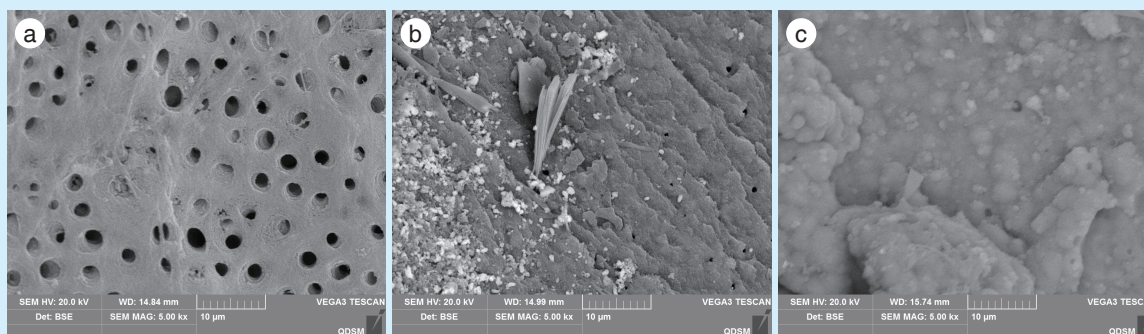
图1 不同方法清除根管内水溶性氢氧化钙与油溶性氢氧化钙的三维重建图

表1 不同冲洗方法清除根管内水溶性氢氧化钙与油溶性氢氧化钙的体积变化

Table 1 Volume comparison of water-soluble calcium hydroxide or oil-soluble calcium hydroxide removal from root canals by different flushing methods

	Water-soluble calcium hydroxide								Oil-soluble calcium hydroxide				F	P
	Water-soluble calcium hydroxide				Oil-soluble calcium hydroxide				F	P				
	SYIG	SOIG	ULIG	LAIG	SYIG	SOIG	ULIG	LAIG						
Upper root canal V ₁	6.06 ± 1.05	6.72 ± 1.51	5.70 ± 0.97	5.85 ± 0.25	5.45 ± 0.73	5.00 ± 1.00	5.67 ± 1.37	5.99 ± 0.95	1.898	0.087				
Middle of root canal V ₁	4.39 ± 0.56	4.29 ± 1.48	3.90 ± 0.75	4.39 ± 0.78	3.44 ± 0.42	3.99 ± 1.48	3.43 ± 0.82	3.39 ± 0.86	1.667	0.136				
Root apical V ₁	2.17 ± 0.64	1.48 ± 0.49	1.81 ± 0.53	2.02 ± 0.95	1.97 ± 0.83	1.67 ± 0.55	1.69 ± 0.69	1.41 ± 0.52	1.273	0.280				
Upper root canal V ₂	5.45 ± 0.73	0.72 ± 0.23	0.11 ± 0.14	0.16 ± 0.17	1.62 ± 0.46	1.21 ± 0.23	1.18 ± 0.31	0.96 ± 0.16	24.796	<0.001				
Middle of root canal V ₂	0.87 ± 0.22	0.64 ± 0.43	0.39 ± 0.16	0.45 ± 0.31	1.52 ± 0.31	1.47 ± 0.68	1.15 ± 0.21	0.81 ± 0.24	15.270	<0.001				
Upper root canal V ₂	0.72 ± 0.23	0.46 ± 0.16	0.49 ± 0.29	0.31 ± 0.21	1.52 ± 0.70	1.09 ± 0.56	1.05 ± 0.77	0.64 ± 0.22	5.997	<0.001				

SYIG: syringe irrigation group; SOIG: sonic irrigation group; ULIG: ultrasonic irrigation group; LAIG: laser-activated irrigation group



a: blank control group, the morphology of dentin tubules in the apical segment were completely open; b: water-soluble calcium hydroxide group, the morphology of dentin tubules in the apical segment were open mostly; c: oil-soluble calcium hydroxide group, the morphology of dentin tubules in the apical segment were not open basically

Figure 2 Morphology of different types of calcium hydroxide residues in root canals observed under scanning electron microscope (×5 000)

图2 扫描电镜下观察根管内不同类型氢氧化钙残留的形态(×5 000)

表2 冲洗方式与消毒药物与根管分段三因素方差分析
Table 2 Three way analysis of variance for irrigation methods and disinfection drugs and root canal segments

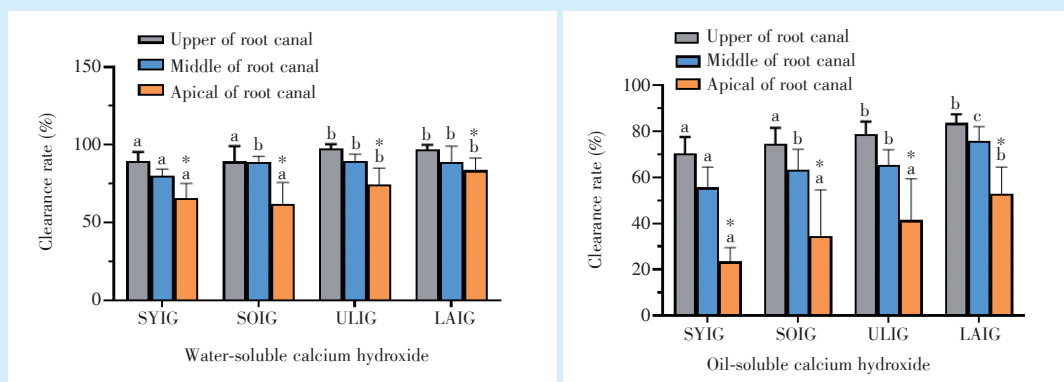
Source	df	RMS	F	P
Source	3	2 361.994	28.396	< 0.001
DM	1	27 722.283	333.284	< 0.001
RCS	2	15 362.442	184.691	< 0.001
RM * DM	3	198.627	2.388	0.071
IM * SRC	6	201.339	2.421	0.029
DM * RCS	2	1 193.29	14.346	< 0.001
IM * DM * RSC	6	67.395	0.81	0.563

DM: disinfectant medicine; RCS: root canal segmentation; RM: rinse method; IM: irrigation method; SRC: segmented root canal

钙,且与根管三段之间比较,根尖 1/3 清除率均较低($P < 0.001$);无论用哪种冲洗方式,在根管各段,油溶性氢氧化钙清除率均低于水溶性氢氧化钙($P < 0.001$)。

对于水溶性氢氧化钙,在根上段与根尖段,Er:YAG 激光荡洗组、超声荡洗组的清除率较高,优于注射器冲洗组与声波荡洗组($P < 0.05$)。在根中段,声波荡洗组、超声荡洗组以及激光荡洗组的清除率均优于注射器冲洗($P < 0.05$),其余三组间无显著差异。

对于油溶性氢氧化钙,在根上段,超声荡洗组、激光荡洗组的清除率较高且优于注射器冲洗组与声波组($P < 0.05$)。在根中段,激光荡洗组的清除率优于其他组,差异均有统计学意义($P < 0.05$),超声及声波荡洗均优于注射器冲洗($P < 0.05$)。在根尖段,激光荡洗组的氢氧化钙清除率优于声波荡洗与注射器荡洗组,差异具有统计学意义,但与超声荡洗组比较差异无统计学意义($P = 0.134$);声波荡洗与注射器荡洗的清除率无显著差异($P > 0.05$)(图3)。



SYIG: syringe irrigation group; SOIG: sonic irrigation group; ULIG: ultrasonic irrigation group; LAIG: laser-activated irrigation group. Different letters indicate significant difference of clearance rate of calcium hydroxide with different washing methods ($P < 0.05$). *: the significant difference of calcium hydroxide clearance in root canal segments ($P < 0.05$)

Figure 3 The removal rate of water-soluble calcium hydroxide or oil-soluble calcium hydroxide removal from root canals by different flushing methods

图3 不同方法清除根管内水溶性氢氧化钙与油溶性氢氧化钙的清除率

3 讨论

根管消毒方式包括超声荡洗^[8]、微波、激光荡洗^[9]和化学消毒法等。为了清除机械消毒的盲区,常常需要根管内封药^[10],即化学消毒。氢氧化钙因其理化性质及抗菌性,为现在最常用的根管消毒药物^[11],其可以与不同的赋形剂结合,现在临床上通常使用水溶性和油溶性氢氧化钙,研究发现油性赋形剂类抗菌性更好^[12]。

根管内残余的氢氧化钙对于根管充填存在不利的影响。研究发现根管内的残余氢氧化钙可以降低AH plus的粘接性^[13-14]。Sokhi等^[4]发现油溶性氢氧化钙导致的根尖微渗漏少于水溶性氢氧化钙。氢氧化钙无法长期维持管内的高pH状态,从而可能导致管内再感染的发生^[15]。有研究发现根管内残余的氢氧化钙还能降低牙本质的硬度^[16]。国内外研究^[17-18]认为使用不同的冲洗方式均无法完全去净管内的氢氧化钙,油溶性氢氧化钙去除更加困难^[19],但是该类研究报道较少。

本研究对比了4种冲洗方式对于两种类型的氢氧化钙的清除效果。结果显示无论哪种冲洗方式,油溶性氢氧化钙的残余量均高于水溶性氢氧化钙。研究认为对于不同赋形剂类型的氢氧化钙来说,粘度越低则水溶性越强,Ca²⁺解离越多,牙本质渗透深度也越浅,越容易被去除^[15]。水溶性的氢氧化钙的粘性低于油溶性,所以更容易去除。本研究中选用的冲洗液均包含EDTA冲洗液,其可解离出Ca²⁺,使得水溶性的氢氧化钙较易被去除^[17]。

注射器冲洗是最简便、最传统的冲洗方式,但是冲洗效率较低^[20],所以需借助其他方式活化冲洗液,提高效率。本实验比较了4种冲洗方式,发现相对于传统的注射器冲洗,Er:YAG激光引发的光声流效应(photon-induced photo acoustic streaming, PIPS)冲洗系统的效率明显提升,尤其是在根尖1/3或者根管侧支等难以冲洗的部位。对于水溶性氢氧化钙,超声荡洗与激光荡洗的清除效率无显著差异。而对于油性氢氧化钙,Er:YAG激光荡洗相对于其他冲洗方式清除率较高,尤其在根尖部位。这是因为Er:YAG激光活化荡洗工作位置不依赖于工作尖所在的位置^[21-22],而是利用脉冲式激光快速激活荡洗液,并使之形成气泡,气泡膨胀后冷却导致的爆破,会对根管壁产生剪切和冲洗即初级空穴效应,大气泡破裂后还会形成小气泡重新次级空穴效应有关^[23]。超声波的震动却只能使工作尖周围的荡洗液形成声波效应及空穴效应^[24]。超声荡洗无次级空穴效应及冲击波,主要是依靠超声尖周围的冲洗液震动,这是与激光荡洗的不同^[22]。

本实验结果发现声波荡洗冲洗效率低于超声荡洗,对比传统注射器冲洗的效率虽然有所提高,但差异无统计学意义,这与部分研究^[15, 25]结果一致。超声波与声波虽然都是由机械振动的能量在弹性介质中传播所形成的,但超声波的波源振动频率高,为 $2 \times 10^4 \sim 5 \times 10^4$ Hz,超声波高频振荡在液体介质中产生空穴效应和热效应,两者协同大大强化了冲洗液的作用^[26]。声波的频率仅为6 000 Hz,

低频振荡在液体介质中不能产生空化作用而使大量液体小泡崩溃,故产生的热效应不足以增强冲洗液溶解氢氧化钙的能力^[6]。超声与声波的工作尖工作模式也不同,超声为横向震动,而声波为环形震动。根尖的管径太小可能阻碍声波工作尖的运动,从而降低其对氢氧化钙清除率^[27]。

检测氢氧化钙清除率或者残余率的常用方法是 Lee 等^[28]提出的标准凹沟法。标准凹沟法是在根管内壁人为地制造一些凹沟,然后根管内填充氢氧化钙,用不同方式去除氢氧化钙后,再次检验凹沟内剩余的氢氧化钙,对剩余量进行评分。此方法主观性较强,而且需要反复劈牙,这个过程中可能导致根管内氢氧化钙的流失,无法准确地比较出各种冲洗方式对于氢氧化钙清除率的差异。目前临床上常用的方法还有扫描电镜法^[17],评分依据为主观性微观观察到氢氧化钙残留封闭牙本质小管,但是无法准确显示出各种清除方式下残余的氢氧化钙的多少。还有近几年国内外研究常用的 CT 测量法估计氢氧化钙的体积^[3,13],但这受制于某些 CT 自带软件无法测量或者无法精确测量其氢氧化钙的体积。

本实验使用的两种氢氧化钙在 CBCT 上的显影程度不同,自带软件无法准确测量。所以笔者借用了 Mimics 软件来测量两种氢氧化钙清除前后的体积, Mimics 可以导入 CBCT 数据,通过不同的阈值对需要的区域进行定位及三维重建,以此来重建出清除前后氢氧化钙三维体积^[21]。此种方法以定量的方式来确定其清除效率,减小了误差,得出了较为准确的数据,清楚地显现出 Er:YAG 激光活化荡洗方面对比其他冲洗方式的优势。电镜下观察发现,两种氢氧化钙均无法完全去除,均可堵塞牙本质小管,油性氢氧化钙堵塞牙本质小管的面积更大,证实了油性氢氧化钙更难去除,从而有可能影响根充糊剂与牙本质小管的粘接,但是还需进一步具体研究证实。

综上,无论何种方法,均不能完全去除氢氧化钙,水溶性氢氧化钙较油性氢氧化钙更容易去除,两者均在根尖部位残存更多。Er:YAG 激光荡洗对比其他冲洗方式有较大优势,尤其在根尖 1/3 的清除效率更高。

[Author contributions] Yang N wrote the article. Wang YY, Shan XY performed the experiments. Du QX collected and analyzed the data. Li NY and Sun HB revised the article. All authors read and approved the final manuscript as submitted.

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(编辑 周春华, 曾雄群)



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