[DOI]10.12016/j.issn.2096-1456.202550320

·综述·

磨牙-切牙釉质矿化不全诊疗策略研究进展

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【摘要】 磨牙-切牙釉质矿化不全（molar-incisor hypomineralization，MIH）是一种牙釉质发育缺陷性疾病，主要表现为第一恒磨牙和恒切牙的釉质矿化异常。由于矿化不充分，MIH患牙易发生牙体缺损和龋坏，进而继发牙齿敏感、咬合问题等。MIH诊断主要依据围产期及婴幼儿时期的相关病史、病损的牙位特征及病损轮廓。根据釉质缺损的范围及严重程度，MIH可分为轻型和重型。诊疗策略强调早期筛查、诊断和干预；预防为主，对症治疗，以及定期复查。轻型MIH主要表现为牙釉质的脱矿性白斑或色泽改变，通常不伴随釉质剥脱；治疗以预防龋坏和美学修复为主，常用方法包括再矿化、微研磨、树脂浸润治疗、漂白治疗、局部涂氟、窝沟封闭等。重型MIH通常表现为严重的脱矿性釉质白斑且伴有釉质剥脱，还可能伴随龋坏、牙齿敏感等；治疗主要为修复牙体缺损或对于无法保留的患牙拔除后正畸治疗等，但常需综合多种治疗方法以恢复牙齿及牙列的功能和美观。本文对MIH的诊疗策略研究进展进行综述，为临床诊疗提供参考。

【关键词】 磨牙-切牙釉质矿化不全；　牙釉质发育缺陷；　第一恒磨牙；　切牙；　诊疗策略；　龋病；　牙体缺损；　口腔健康

【中图分类号】 R78　**【文献标志码】** A　**【文章编号】** 2096-1456（2026）03-0292-10

微信公众号

【引用著录格式】 赵芳，王欣，黄进伟，等. 磨牙-切牙釉质矿化不全诊疗策略研究进展[J]. 口腔疾病防治，2026, 34(3): 292-301. doi:10.12016/j.issn.2096-1456.202550320.

Advancements in the diagnosis and treatment strategies for molar-incisor hypomineralization

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【Abstract】 Molar-incisor hypomineralization (MIH) is a developmental defect of enamel that is characterized primarily by abnormal enamel mineralization affecting the first permanent molars and permanent incisors. Due to insufficient mineralization, teeth affected by MIH are prone to post-eruptive breakdown and caries, potentially leading to sequelae such as tooth sensitivity and occlusal problems. The diagnosis of MIH is primarily based on relevant perinatal and infantile medical history, the characteristic distribution of affected teeth, and the morphological features of the enamel defects. Based on the extent and severity of the enamel defect, MIH is classified as mild or severe. Diagnosis and treatment strategies emphasize early screening, diagnosis, and intervention, prioritizing prevention, providing symptomatic care, and implementing regular recall assessments. Mild MIH predominantly manifests as demineralized enamel opacities or discoloration, typically without significant enamel breakdown. Treatment focuses on caries prevention and aesthetic restoration, employing techniques such as remineralization, micro-abrasion, resin infiltration, bleaching, fluoride

【收稿日期】 2025-07-24；　**【修回日期】** 2025-09-15

【基金项目】 北京市自然科学基金面上项目（7242172）；北京大学口腔医院临床新技术新疗法项目（PKUSSNCT-25A13）

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application, and fissure sealants. Severe MIH typically presents with extensive enamel opacities accompanied by substantial enamel breakdown and may be complicated by caries and tooth sensitivity. Management primarily involves restoring the structural defects or, for teeth that cannot be preserved, extraction followed by orthodontic treatment. Comprehensive management often requires a multimodal approach integrating various therapeutic modalities to restore both the function and aesthetics of the affected teeth and overall dentition. This article provides a review of advancements in diagnosis and the treatment strategies for MIH, offering a reference for clinical practice.

【Key words】 molar-incisor hypomineralization; developmental defects of enamel; first permanent molar; incisor; diagnosis and treatment strategies; dental caries; dental defects; oral health

J Prev Treat Stomatol Dis, 2026, 34(3): 292-301.

【Competing interests】 The authors declare no competing interests.

This study was supported by the grants from Beijing Natural Science Foundation General Program (No. 7242172); Program for New Clinical Techniques and Therapies of Peking University School and Hospital of Stomatology (No. PKUSSNCT-25A13).

磨牙-切牙釉质矿化不全(molar-incisor hypomineralization,MIH)属于釉质矿化不全疾病的一种,指由于全身因素导致一颗或一颗以上的第一恒磨牙(first permanent molars,FPM)釉质矿化不全,常伴切牙受累[1]。

第一恒磨牙的釉质从出生时开始形成,至2.5~3岁发育完成;切牙的釉质则从出生后3~12个月开始形成,至4~5岁时发育完成。因此大多数针对MIH病因的研究都集中于从妊娠期到出生后前3年的环境和全身因素调查[2-3]。一项Meta分析显示,特定围产期因素(如宫内缺氧、剖宫产分娩、早产等)以及婴幼儿期罹患某些疾病(如麻疹、尿路感染、支气管炎、中耳炎、胃肠道疾病、肾脏疾病、肺炎及哮喘等)与MIH的发生存在显著相关性;婴幼儿期的发热和使用抗生素也与MIH相关[4]。此外,一些研究还指出MIH的发生与遗传易感性及表观遗传调控有关[5-6]。

流行病学调查显示全球MIH的患病率因受调查的地域和年龄不同而相差较大,为2.8%~40.2%[7-8]。曾有流行病学调查显示巴西和叙利亚地区7~13岁儿童MIH患病率高达40%[9-10],我国6~15岁儿童MIH患病率为2.8%~25.5%,但是仅局限于某些个别地区的调查研究,尚缺乏有综合阐述我国MIH患病率的研究[11-12]。由于上颌侧切牙在8~9岁完全萌出,因而评估MIH的最佳年龄为8~11岁,尤以9岁最为常见[13]。

本文系统综述了MIH的诊疗策略,旨在为临床医生提供全面的诊疗指导,以改善MIH患者口腔健康,提升其生活质量。

1　MIH的诊断标准、分型、临床表现及鉴别诊断

1.1　MIH的诊断标准

欧洲儿童牙科学会(European Academy of Paediatric Dentistry,EAPD)2022年发布的指南[14]中,总结MIH诊断标准如下。

1.1.1　牙位特征　①1~4颗FPM存在釉质矿化不全;至少1颗FPM受累才能诊断为MIH;恒切牙也可受累;②磨牙受累越严重,切牙的受累程度越高,釉质缺陷越显著;③受累的磨牙和切牙数目越多,病损越严重;④病损也可发生在第二乳磨牙、前磨牙、第二恒磨牙和尖牙。

1.1.2　病损表现　①边界清晰的釉质不透明斑块,表现为釉质透明度改变;②颜色、大小和形状存在差异;可呈白色、乳白色、黄色至棕褐色;③只有病损直径超过1 mm时才建议诊断为MIH。

1.1.3　牙体缺损表现　①严重受累的釉质在牙齿萌出后,因咀嚼力作用而发生剥脱;②表层釉质剥脱后,残余的低矿化区域呈不同程度蜂窝状表现;③剥脱部位牙本质暴露,以及可迅速发展为龋坏。

1.1.4　牙齿敏感　①受累牙常出现敏感症状,程度不一,可表现为对外部刺激的轻微反应至自发性敏感不等;②MIH磨牙可能麻醉效果不佳。

1.1.5　牙体缺损充填修复特征　①充填体的轮廓与常规龋洞形态不符;②后牙修复体常可延伸至不易患龋的颊面或腭/舌光滑面;③在修复体边缘经常可以观察到边界清晰的不透明斑块;④FPM和恒切牙的充填体范围与MIH所致的釉质着色斑块呈现相似的范围特征。

1.1.6　因MIH导致恒磨牙早失　以下情形可推断恒磨牙早失由MIH引起:①病历记录显示早失患

牙存在MIH；②其他FPM出现边界清晰的不透明斑块或非典型充填体；③恒切牙存在边界清晰的不透明斑块。

1.2　MIH的分型及临床表现

根据是否存在牙釉质缺损，EAPD将MIH分为轻型和重型[14]。

轻型MIH临床表现（图1）：①有界限清晰的釉质不透明区，无釉质缺损；②外部刺激（如空气/水）诱发敏感，但刷牙刺激除外；③切牙变色，呈现轻微的美观问题。

重型MIH临床表现（图2）：①有界限清晰的釉质不透明区，且伴有釉质缺损和龋坏；②自发且持续的牙齿敏感，影响功能（如刷牙、咀嚼）；③严重的美观问题，可能对心理产生影响。

An 8-year-old female patient with mild enamel hypomineralization of the permanent incisors and first permanent molars, characterized by demarcated enamel opacities without enamel breakdown or caries (yellow arrows). MIH: molar-incisor hypomineralization

Figure 1　Intraoral photograph of an 8-year-old female patient with mild MIH

图1　8岁女性轻型MIH患儿的口内像

A 9-year-old male patient with varying degrees of enamel hypomineralization affecting multiple permanent incisors, first permanent molars and primary molars. The labial enamel of the right maxillary lateral incisor, left maxillary central incisor, left mandibular lateral incisor, right mandibular central incisor, and right mandibular lateral incisor exhibit opaque discolored areas without enamel defects (yellow arrows). The right maxillary central incisor, bilateral maxillary and mandibular first permanent molars, and right mandibular second primary molar show enamel opacities accompanied by enamel breakdown and caries (green arrows). Caries lesions in the left mandibular and bilateral maxillary second primary molars have progressed to residual crowns and roots (blue arrows). MIH: molar-incisor hypomineralization

Figure 2　Intraoral photograph of a 9-year-old male patient with severe MIH

图2　9岁男性重型MIH患儿口内像

1.3　MIH的鉴别诊断

MIH易与遗传性釉质发育不全、环境性釉质发育不全及氟斑牙相混淆，其鉴别要点主要体现在：①遗传性釉质发育不全：通常累及全牙列，常有家族史[15]；②环境性釉质发育不全：病变呈水平性分布，釉质白垩色斑块边缘比较明确和规则[16]；③氟斑牙：一般为弥漫性对称性病损，具有一定抗龋性[16]。

2　MIH治疗策略

MIH患牙受累区域釉质矿化程度低，表现为釉质表面边界清晰的不透明斑块；釉质孔隙率增加、硬度和弹性降低[17]，易磨耗及剥脱导致釉质缺损，进而由于牙本质暴露引起牙齿敏感，疼痛阈值下降[18]；继而导致该处口腔卫生维护不佳，菌斑堆积，易发龋病，且龋坏进展迅速[19]，甚至引起牙髓感染[20-21]，导致牙齿早失等[22-23]。此外，患者常因前牙美观欠佳影响社会交往，因牙齿敏感、牙齿早失影响咀嚼进食，甚至引发牙科焦虑和恐惧等[24-25]，这些都严重影响患者的生活质量和身心健康，所以早期诊断与及时治疗非常重要[26-27]。

基于MIH不同程度的临床表现、患者年龄以及行为管理效果等要素，其治疗策略也不同。总体治疗目标包括：缓解或消除症状；修复缺损，恢复正常咬合关系与牙列间隙；改善功能与美观，提高患者生活质量与自信心[14]。制定治疗计划时，需综合考量患者年龄、牙齿发育情况、牙釉质缺损程度、牙齿美观要求、口腔卫生情况、对口腔治疗的配合程度、经济条件等因素，且需充分考虑到可能出现的并发症和风险[14, 28]。年轻恒牙的髓腔大、髓角高、牙冠主动萌出或被动萌出不足，应遵循微创治疗原则，并尽量在橡皮障隔离下进行治疗[14]。

2.1　MIH的预防管理

早期识别并诊断MIH是管理此类患者的关键。因MIH患牙龋坏风险高[29-30]，所以早期防龋格外重要。MIH患牙通常对外界刺激敏感[31-32]，患儿往往主观排斥刷牙、漱口等口腔保健行为[33]，因此需定期向患儿及其家长提供口腔卫生维护及饮食指导，强化口腔卫生宣教。MIH患牙无论是否完全萌出，都建议定期使用氟化物防龋[34-35]；完全萌出的磨牙，应尽早行窝沟封闭预防龋病及釉质磨损或剥脱[36]。有研究发现不透明斑块的颜色越深，萌出后釉质剥脱的可能性越大，而且磨牙比切牙更易发生牙体组织剥脱，可能与其承担较大的咬合力有关[19]。

2.2　轻型MIH的治疗

2.2.1　轻型MIH恒切牙治疗　轻型MIH切牙主要表现为由于釉质透明度和色泽的改变引起美观欠佳，治疗方法包括再矿化、微研磨、树脂浸润治疗、漂白治疗等[37-38]。前牙变色可能会对患儿的社会交往和心理发育产生不良影响[39-40]，有研究表明治疗后患儿的整体口腔健康水平及口腔健康相关的生活质量均有所改善[41-42]。

微研磨治疗主要针对白色或奶油色的不透明斑块。在橡皮障严密隔湿和保护软组织基础上，使用18%盐酸或37%磷酸，与浮石或碳化硅等磨料进行微研磨，之后将再矿化剂涂布在微研磨处，以改善前牙美观[43]。一项随机临床试验研究显示微研磨组后涂布酪蛋白磷酸肽-无定形磷酸钙促进再矿化，与仅进行微研磨组相比，6个月后牙齿获得更理想的美学效果[43]。

树脂浸润治疗对改善釉质层黄色至褐色的不透明变色有一定效果，既往报道治疗后6个月效果稳定[44-45]。具体流程为充分清洁牙面、去除菌斑后，使用15%~20%盐酸酸蚀釉质、99%乙醇去除病损表面微孔内残余水分，之后让具有流动性的渗透树脂在毛细作用下逐渐渗透到病灶体内，从而改善病损部位的光学特性及整体颜色[44, 46]。既往报道中使用树脂浸润治疗MIH患者的最小年龄为7岁[47]。然而因树脂材料本身易老化着色，治疗后需格外注意口腔卫生维护[48]。这项技术的远期效果仍需基于大样本量、长时间随访的高质量临床研究来证实[49]。

此外，有文献指出可以使用过氧化物漂白来改善前牙颜色，或将漂白方法与微研磨或树脂浸润治疗结合使用[50-51]，但漂白的安全性及副作用不容忽视，如牙龈刺激、牙齿敏感等[52-53]。尤其对于年龄较小患儿，治疗安全性至关重要[54]。EAPD指南中提到欧盟对儿童患者使用的牙齿美白治疗限制在0.1%过氧化氢[14]，我国对未成年人的牙齿漂白治疗尚无专家共识类指南文件，多数学者认为应在患儿成年后再考虑漂白治疗[55]。

2.2.2　轻型MIH恒磨牙的治疗　治疗轻型MIH恒磨牙需将患者的自我管理和口腔门诊治疗相结合，开展双重防治[56]。首先应充分告知疾病的严重性，争取患者积极配合。患者可尝试使用氟浓度大于1 000 ppm的高含氟牙膏，使用2~4周后敏

感症状无缓解，则酌情采取门诊治疗措施[47]。也可酌情使用脱敏牙膏，如含精氨酸的牙膏[57-58]。

轻型MIH恒磨牙临床治疗主要包括局部涂氟和窝沟封闭治疗[47,59]。局部应用氟保护漆或氟凝胶可显著减轻超敏反应和促进釉质再矿化[60-61]。窝沟封闭可以很好地预防磨牙窝沟龋发生。尚未完全萌出的MIH恒磨牙或不合作患儿，可选用对隔湿要求不高的含氟玻璃离子水门汀（glass ionomer cement，GIC）进行窝沟封闭[62]。但GIC机械性能较差，与树脂基封闭剂相比，远期保留率较低[63-64]。因此，待磨牙完全萌出后，应及时将GIC更换为树脂基封闭剂。对于已完全萌出（主动萌出接近完成）且无釉质缺损的恒磨牙，在涂布窝沟封闭剂之前，可辅助使用粘结剂以增强窝沟封闭剂的固位力[65]。此外，有学者利用Er：YAG激光与脱敏剂联合治疗取得了满意的临床效果，为治疗MIH牙齿敏感提供了更多选择[66-67]；一项随机对照临床试验研究发现Nd：YAG激光可以产生即刻脱敏效果，而氟保护漆产生延迟脱敏效果，两者联合使用比单独治疗的脱敏效果更好[68]。

2.3　重型MIH的治疗

2.3.1　重型MIH恒切牙的治疗　重型MIH患牙表现为不同程度的釉质实质性缺损。若切牙的缺损仅为唇面点状凹陷，且无明显敏感症状，治疗目标主要为防龋，在加强口腔卫生维护的基础上，治疗方法与轻型MIH相同，一般可获得良好的效果[69-70]；若釉质缺损广泛或较深，应早期行树脂充填，无论是否去除釉质，其均可修复缺损和遮盖颜色[71-72]。

对于颜色较深的不透明病损可在遵循微创治疗的原则以避免露髓的基础上选择去除部分釉质，也可在树脂充填前涂抹遮色剂从而避免去除过多釉质[73]。树脂修复后需定期随诊观察是否出现边缘着色、修复体折断、继发龋等。对于接近成年的青少年患者，可酌情选择贴面、全冠等间接修复方式[14]。

2.3.2　重型MIH恒磨牙的治疗　重型MIH恒磨牙往往表现为釉质缺损、牙齿敏感、大面积龋坏、非典型充填体、残根残冠等，需综合判断以选择合适的治疗方案。

对于未完全萌出的磨牙或不合作患儿，可酌情使用GIC或树脂改性GIC进行过渡性治疗，但既往报道治疗成功率整体较低且差异较大[74-75]。临床上GIC通常被用作过渡性修复材料，待患者可配合树脂充填治疗或磨牙完全萌出后建议及时更换为树脂材料[76-77]。

对于就诊时已完全萌出的磨牙，在橡皮障隔离下去除全部或部分矿化不足的釉质，采用直接法复合树脂充填修复可以取得较高的成功率[60,78]。树脂材料与MIH患牙釉质的粘接强度较低，但与牙本质的粘接强度不受影响[79]。因此，一般建议完全去除位于窝洞边缘的低矿化釉质，直至暴露健康釉质[80]。一项回顾性队列研究显示按此标准治疗比保留洞缘部分低矿化釉质后树脂修复，治疗3年成功率高约50%[81]。此外，化学去腐与抗菌光动力疗法（antimicrobial photodynamic therapy，aPDT）联用也是一种微创治疗选择，以期最大限度地保留健康的牙体组织[82]。有体外和临床研究表明aPDT可增强修复体与牙体之间的粘接强度[83-84]；其疗效仍需高质量的临床研究来证实[85]。

对于MIH累及多个牙面、多个牙尖的大面积牙体缺损，正畸带环联合直接法充填修复可作为一种临时治疗方法[86]；采用金属预成冠（stainless steel crown，SSC）修复也能实现单次治疗即可完成修复，达到防止牙体组织继续破坏脱落、控制敏感、维持三维空间关系的目的[79,87]。但是这两种方法均美观欠佳，且可能对牙周健康产生不良影响[88]。

此外，可采用嵌体、高嵌体、全冠、嵌体冠等间接修复体来治疗MIH大面积牙体缺损，与直接复合树脂充填相比可获得更高成功率[89]。儿童患者修复常使用树脂陶瓷复合材料[14]。与SSC修复相比，间接法制作的修复体边缘一般位于龈上，减少了对牙周组织的影响，且美观性好[90]。间接法修复治疗，牙体预备时建议去除所有低矿化釉质，以确保实现牙冠与健康釉质粘结[14]。总体而言，间接法修复对医生操作和患儿配合程度要求均较高[91]。若计划复诊时粘接修复体，还需制作临时修复体以维持患儿的咬合间隙。应用计算机辅助设计与制造技术实现数字化操作，可大幅度提高修复体制作效率，单次就诊即可完成全部修复过程[92-93]，为MIH患者的修复治疗提供了新的可能性，然而该技术的治疗效果还需更多长时间随访临床研究来验证[94]。

对于残根、残冠、根尖周炎、牙周脓肿等长期预后不佳的MIH患牙，可酌情选择计划性拔牙。拔牙时机需特别关注，建议在8~10岁第二恒磨牙

发育时期拔除第一恒磨牙[95-96]，使第二恒磨牙有机会自发萌出到第一恒磨牙的位置，期待在无正畸干预的前提下间隙自然关闭，但需明确，并不能保证所有间隙都能自然闭合[97]。有研究调查上颌第一恒磨牙和下颌第一恒磨牙拔除后间隙自然闭合的成功率分别为85.3%和48.1%[98]。因此，建议在计划性拔牙前先进行正畸咨询与影像学检查[99]，评估患儿牙列发育阶段、是否有潜在的错𬌗畸形等，以便综合制定治疗计划。

2.4　定期复查

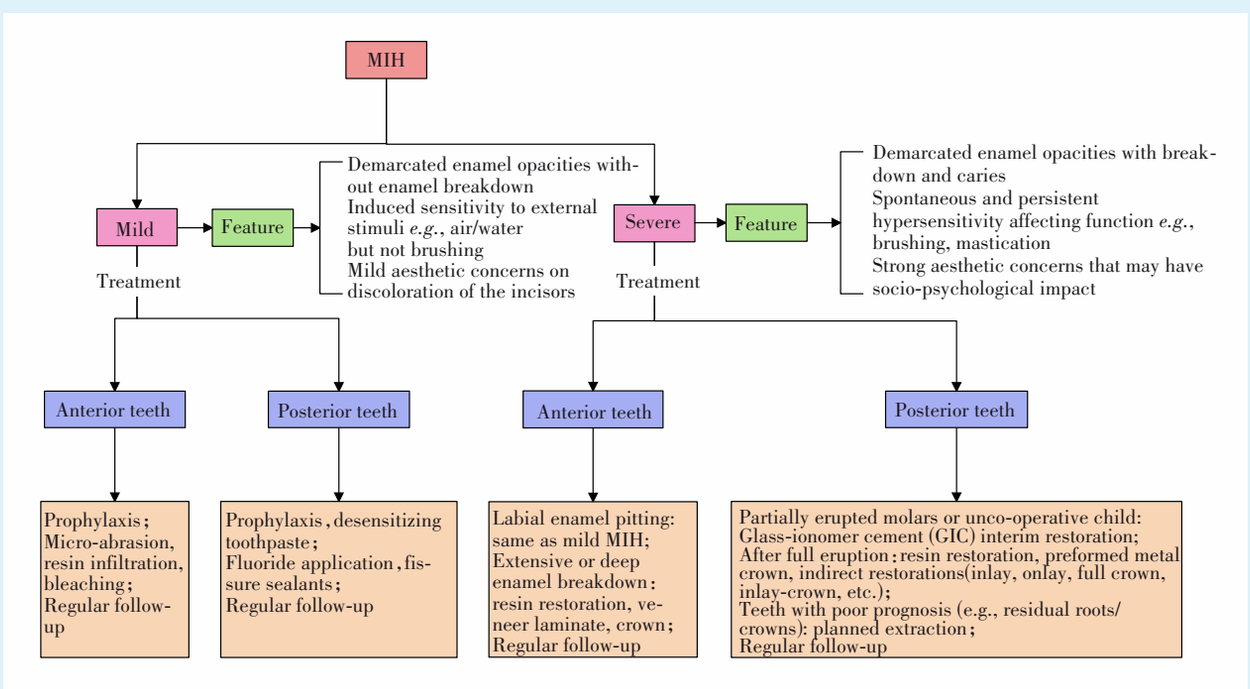
MIH患牙患龋倾向性高，建议每3~6个月定期检查，进行专业的预防管理，对口腔疾病早发现、早治疗[100]。

3　总结与展望

随着材料学和方法学的进步，MIH患牙的诊疗策略在近年来有较大更新：强调早期筛查、诊断和干预；预防为主，对症治疗，以及定期复查。

轻型MIH主要表现为牙釉质脱矿或色泽改变，通常不伴釉质缺损，治疗以防龋和美学修复为主；重型MIH通常表现为严重的釉质脱矿和缺损，可能伴随龋坏、牙齿敏感等；治疗主要为修复牙体缺损或对于无法保留的患牙拔除后正畸治疗等（图3）。

对MIH的治疗常需综合多种治疗方法以恢复牙齿及牙列的功能和美观。随着医学观念的进步和人们对口腔健康的日益重视，使MIH的早发现、早诊断、早治疗关口逐渐前移，这也突出了治疗后定期随访维护的重要性，对口腔保健提出了更高要求。此外，由于MIH至今病因未明，未来围绕MIH的研究方向可能为病因学研究，以及围绕牙体缺损修复效果和美学效果的治疗方法学研究。



MIH: molar-incisor hypomineralization

Figure 3　Diagnosis and treatment strategy for MIH

图3　MIH诊疗策略

【**Author contributions**】 Zhao F did the majority of the literature research and prepared the first draft of the manuscript. Wang X, Huang JW and Liu JP revised and proofread the manuscript. Xu H conceptualized the research and reviewed the manuscript. All the authors have read and approved the final manuscript as submitted.

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