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REVIEW

Treatment management of extensive defects of vital first permanent molars in children

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Abstract

The integrity of the dental arch is crucial for normal oral and maxillofacial function and aesthetics. Due to a low degree of enamel and dentin mineralization, poor oral hygiene and risk of molar incisor hypomineralization (MIH), children's first permanent molars can be associated with an increased risk of caries and defects. Dental hygiene requires proper instruction and continuous support by the parents to enable healthy tooth development in children. Otherwise enamel and dentin defects can progress rapidly and eventually impact the dental pulp and even periapical tissues. When treating children with mixed dentition, treatment methods must consider important factors including the development of soft and hard tissues, occlusal remodeling, patient cooperation and control of pain and discomfort, as well as child-specific treatment approaches tailored to the developing dental and oral system. This article provides a retrospective summary and discussion of the latest treatment methods for extensive enamel and dentin defects in vital first permanent molars in pediatric patients, serving as a reference for clinical treatment.

Keywords

Dental restoration; Molar; Permanent; Dental materials; Pediatric dentistry; Tooth extraction; Children

1. Introduction

Healthy first permanent molars (FPMs) are crucial for the development of children's oral and maxillofacial systems. Once FPMs erupt, they gradually come into contact with the opposing dentition and, under the influence of the cheek and tongue muscles as well as bite force, FPMs establish a stable occlusal relationship. Extensive defects FPMs development disrupt the above processes. In severe cases, children may develop unilateral chewing, ultimately leading to abnormal facial development and impaired physical and mental health [1, 2].

In previous studies, the prevalence of caries affecting FPMs in 12-year old children ranged from 36.64% to 83%, depending on the population studied [3–5]. Due to early eruption, low mineralization, risk of Molar Incisor Hypomineralization (MIH) [6], and the presence of structures such as sulci, fissures and enamel plates, along with poor oral hygiene in children, FPMs have a higher incidence of caries than other teeth in the developing oral cavity [7]. However, some parents mistakenly consider permanent molars as primary molars, leading to their reluctance to seek timely medical attention for their children. This often results in the discovery of extensive dental caries only when treatment is sought [8]. Developmental defects of enamel and dentin may also lead to extensive defects in dental tissue, such as MIH [9], dentinogenesis imperfecta (DI) [10] or amelogenesis imperfecta (AI) [11]. In addition, severe hereditary anomalies are often accompanied by extensive enamel disintegration and caries [12].

Due to the inability to establish a good occlusal and adjacent relationship with the opposite jaw and adjacent teeth, the affected teeth with large defects cause excessive over-eruption of the opposing dentition and inclination of the adjacent teeth. This impacts food retention of the affected teeth and decreases their self-cleaning abilities, which together aggravate caries formation in the immediately affected as well as distal teeth. Therefore, timely prevention and of necessary appropriate restoration are crucial. However, in practical clinical work, due to the limited level of cooperation among pediatric patients, as well as the characteristics of short clinical crowns, large pulp chambers and high pulp horns, the restoration of large-scale defects is further complicated [7, 13].

When treating teeth with extensive dental defects, defined as *involving* at least two surfaces or one-third of the dental tissue, it is essential to consider factors beyond the retention and resistance form of the restoration. Furthermore, the protection of the remaining dental tissue should be a priority. For children (under the age of 12 years old), appropriate sedation and analgesia methods are necessary to maintain comfort and prevent painful treatment experiences, that would impact future treatments [14]. Due to the presence of hypersensitivity caused by deep caries or/and MIH, pain control is a fundamental issue [15]. Dental general anesthesia (DGA) is a safe and effective method for the pediatric patients. However, DGA acceptance by insurances and parents varies from 10% to 70% [16, 17]. For children whose parents are unable to accept DGA, repairing PFMs with extensive defects under local anesthesia presents a significant challenge.

Restoration methods for extensive defects of FPMs include direct and indirect restorations, while indirect restorations vary depending on whether the pulp is removed or not, with or without core placement. This article mainly discusses the direct and indirect restoration options for vital pulp teeth that do not invade the pulp cavity.

2. Direct restorations

2.1 Composite resin restorations

The composite resin restoration is currently the commonly used method for tooth defects [18]. It has excellent aesthetic and mechanical properties, ease of handling, and it preserves more of the dental tissue [19]. With the development of dental materials, the indications for resin restoration have become increasingly popular. Guidelines published by the Academy of Operative Dentistry Europe Section (AODES) in 2014 stated that composite resin is the preferred material for posterior tooth restoration, despite the fact that resin restoration should be carefully selected in cases of poor development of dentin and enamel [20]. For small-scale dental defects, direct resin restoration is always the preferred treatment option.

The ideal composite resin direct restoration method requires a standardized operation, which poses high requirements for both dentists and patients [21]. Currently, most resin fillers require layered solidification due to polymerization shrinkage and the influence of light depth [22]. When there is a large area of tooth defects, the appearance and shape of the restoration is more time-consuming, which can implicate in the final result because young patients have limited cooperation. Insufficient eruption of the FPMs in pediatric patients often results in the gingival marginal and extensive defects being located beneath the gingiva, making it difficult or even impossible to install a rubber dam required for the restoration process. In addition, for extensive defects FPMs it is difficult to remodel good occlusal morphology and interproximal contact with resin restoration [21].

Several studies have shown that restoration with composite resin is a predictable option [23–25]. However when dealing with teeth affected by developmental defects like MIH, structure, chemical and mechanical properties of enamel should be considered [6]. Due to poor adhesion of remaining enamel and reduced bond strength, it is suggested that all of the hypomineralised enamel is removed for long-term success [6]. Generally, the success rate of direct restoration of posterior teeth is high. However, attention should be paid to potential failures mainly caused by secondary caries and fractures within the restoration area [26, 27]. The polymerization shrinkage of composite resins during the curing process is an inherent problem of the composite material. Long-term shrinkage leads to complications such as postoperative sensitivity, secondary caries and delamination of the bonding interface [18]. To improve the composition of composite resins, addition of inorganic particles could control the polymerization shrinkage [28]. Furthermore, some study has attempted to introduce bioactive particles into inorganic fillers to provide exogenous mineralization ion sources. These approach helps to compensate for early demineralization and caries development, and it induces remineralization at the bonding interface [29].

The more dental structure remaining, the better the long-term prognosis of teeth Study has shown that as the amount of missing tooth tissue walls increases, the 5-year failure rate of resin restorations gradually rise [30]. The enlargement of the defects frequently leads to problems such as thin tooth tissue walls and fragile tooth cusps. During the resin restoration process, polymerization shrinkage may cause deformation of the weak tooth tissue wall, and the lateral occlusal forces intensify the deformation and leads to tooth fracture [31]. Currently, there is still insufficient evidence regarding what constitutes a safe minimum thickness for cavity walls [31]. A current study shows a minimum thickness of more than 2 mm at the bottom of the remaining tooth cusp enables a more effective direct restoration [32]. When the wall of the cavity is less than 1 mm, it is recommended to restore indirectly with a cusp coverage approach [31]. Generally, researchers recommend that when the width of the defects is more than 2/3 of the distance between the buccolingual cusps, or when the remaining tooth tissue is less than 1/2 of its original size, direct restoration is difficult to provide sufficient coronal protection, and indirect restoration is a more appropriate choice [33, 34].

2.2 Glass ionomer cement

Glass ionomer cement (GIC) is another type of direct restoration material, that produces direct chemical bonding and is easy to use. The unique advantage of GIC lies in its sustained fluoride release ability and its ability to act as a fluoride reservoir [35]. Fluoride can not only disturb the formation of plaque biofilm but also promote the remineralization when the tissue is demineralized [36]. Studies have shown that GIC can reduce mineral loss by at least 80% within 0.22 mm of adjacent dental tissue [37]. In addition, as a water-based cement, the wet tooth surface at the initial stage of curing is conducive to its bonding [38]. Therefore, the requirements for moisture isolation are not as strict as those for resin restoration. An important consideration in pediatric dentistry is the cooperation of children during dental procedures [7]. Therefore, the above characteristics of GIC also make it widely used for pediatric patients [39].

Some studies have indicated that in teeth affected by MIH, dentin is highly sensitive, the crowns often exhibit extensive demineralization, and the bonding with resin during restoration is unsatisfactory. In such cases, GIC has shown better results [40, 41]. Furthermore, due to the poor cooperation and inadequate moisture control in the case of children, the effect of resin restoration is unsatisfactory. Therefore, GIC could be used as an interim restoration to be replaced by resin-based restoration when conditions are suitable.

Considering the insufficient pressure and abrasion resistance, many improvements have been made in the composition of traditional GIC. In a new generation of GICs, one approach *involves* incorporating silver alloy particles into ionomer glass portions and fusing silver powder particles with glass to create a metal-modified glass ionomer cement [42]. Furthermore, incorporating zirconia ceramic particles achieves greater compressive and flexure strengths and provides reduced occlusal wear along with fast setting reaction times, which make this approach a good option for enamel restoration [43]. Resin-modified glass-ionomers (RMGIs) have also been introduced. These contain hydrophilic monomers and polymers such as hydroxyethyl methacrylate (HEMA) [44]. A recent study suggests that RMGI typically has better mechanical properties compared to traditional GIC [44]. Although significant improvements have been achieved in GIC, evidence is still lacking on whether it can maintain long-term stability in the restoration of extensive PFMs.

3. Indirect restoration

While direct restoration aligns more closely with the current concept of minimally invasive prosthodontics [45], in cases *involving* thin-tooth tissue walls and weak cusps, direct restoration without cusps coverage cannot adequately protect the fragile remaining tooth structure [46]. Therefore, appropriate indirect restoration is necessary. Studies have shown that the number of dentin walls is closely related to the fracture strength of teeth. Each increase in missing tooth tissue wall increases the risk of indirect restoration failure by about 30%–40% [26, 30, 47]. Therefore, indirect restoration is a more appropriate option when a large area of defects lead to thin dentine walls [31]. However, it should be noted that the pulp cavity of FPMs in children is wider and the pulp horn is high, thereby leading to an increased risk of pulp exposure during tooth preparation of indirect restoration [7, 13].

Indirect restorations mainly include inlays, onlays, crowns, endocrowns and post-core crowns. Inlays neither support nor cover the cusp, have no protective effect on the remaining tooth tissue [48], and they may even produce a wedge force unfavorable to the tooth tissue, making them unsuitable for restoring large area defects Endocrowns and post-core crowns are mainly used to restore pulpless molars [49]. Therefore, this article mainly discusses the use of onlays and crowns in vital pulp FPMs.

3.1 Onlay restorations

Onlays are restorations that cover at least one cusp of a teeth. They can restore the shape of tooth and protect the remaining tooth tissue [50]. The edge line of the onlays is more complex than that of crowns. Therefore, obtaining accurate impressions in children with silastic or polyether rubber is difficult due to the gag reflex associated with this procedure [51, 52]. Therefore, the use of onlays in pediatric patients is not very common. In recent years, due to the increasing popularity of computer-aided design/computer-aided manufacturing (CAD/CAM) and other technologies including portable intraoral scanning equipment, dentition models in children can be obtained more quickly and accurately. Furthermore, owing to the development of adhesives and resin-based ceramics as well as other materials, the preparation of onlays that are accurately adjusted to the cavity shape, and the edge line are also gradually being facilitated. The emergence of new materials including the resin-based ceramics that closely mimic the elastic modulus of dental tissue, partially offsets previous concerns about the material's mechanical properties. At present, onlays are widely used in the restoration of large-area defects molars. In addition, medical indications that can be addressed with onlays are even more frequently seen in dentistry than indications for full crowns onlay [53, 54].

Onlay restoration in dentistry has the following advantages: (1) Covering the tooth cusps to restore the tooth morphology, changing the tensile stress to compressive stress, and reducing the risk of tooth fracture; (2) The tooth preparation for onlays *involves* about 34%–39% of the tooth, while that for crowns is about 67.5%–75.6% [55]; (3) The integrity of the tooth cervical can be preserved without grinding the tooth tissue on the axial surface, destroying the adjacent surface of the non-defect side and the contact point; (4) The marginal line is generally located above the gingiva, which is conducive to the health of periodontal tissue; (5)The fracture mode of onlays, in cases where this occurs, is more favorable for future repair in the specific area than the fracture mode of crowns. Most fractures do not *involve* the root of the tooth. If the tooth were fractured, full crowns, post-core crowns, and other restorations can be performed according to the situation. Two studies have also confirmed the excellent restoration effect of onlays in children [13, 56].

In recent years, advancements in bonding technology and materials have facilitated the increasingly widespread application of onlays in dental restoration. Because current onlay restorations mainly rely on bonding and retention, it is critical that there is enough intact tooth enamel bonding area to ensure a stable and functional long-term outcome. Research has shown that reliable bonding effect could be achieved only when the remaining amount of enamel exceeds 50%, the enamel bonding surface accounts for more than 50% of the total bonding area, and the enamel bonding edge line accounts for more than 70% of the total bonding edge line, reliable bonding effect could be achieved [57, 58]. Therefore, for molars with defects exceeding 50% of the tooth, or when the enamel is extensively damaged and the bonding area is insufficient for durable onlay integrity, restoration with crowns is the choice of treatment to ensure improved long-term outcomes.

Currently, there is a lack of relevant scientific evidence regarding the minimum thickness of tooth walls. This creates some uncertainty in the preservation of tooth tissue and the removal of cavities. Additionally, various parameters can influence the decision-making process for the dentist. It is generally agreed that for large-area defects in thin-walled cavities, indirect restoration should be preferred over direct restoration [31].

3.2 Conventional preparation crown restoration

Crowns are the most commonly used method to repair large area tooth defects, as crowns have a good protective effect on weak tooth tissue. Numerous studies have confirmed that full crowns provide lasting protective effects on posterior teeth with large area defects [59]. Some scholars have performed crown restorations on the first molars of children aged 6 to 8 years. In cases *involving* enamel developmental defects, the results after 2 to 5 years of follow-up have been very satisfactory [60]. For vital pulp molars with large area defects, the study also confirmed that the overall success rate of full crown restorations over a period of 5 years was much higher than that of direct restorations when less than two complete tooth tissue walls were retained [30].

It is generally believed that the occluso-cervical height of abutment teeth is the most important factor that affects the retention of full crowns. When occluso-cervical height is less than 3 mm [61], it cannot provide an effective retention form, and the restoration is more prone to fall off. Therefore, the gingival attachment level of the first molar directly affects the repair space [62]. However, in clinical dental practice, the crown of the FPMs in children is relatively short, and the pulp cavity cannot be used for retention. These facts limit the application of full crown restorations in pediatric dentistry. Nowadays, the concept of restoration increasingly emphasizes the preservation of natural tooth tissue. The necessity of more extensive abutment preparations and the incurred pericervical dentin damage in crown restoration procedures, are inconsistent with current development trends [63]. Therefore, for pediatric patients, conventional preparation crown restorations should be chosen cautiously.

3.3 Indirect restoration materials

At present, the commonly used ceramics in dental restoration are divided into three categories: polycrystalline ceramics, such as alumina ceramics and zirconia ceramics; Glass-matrix ceramics, such as feldspar ceramics, lithium disilicate ceramics and resin-matrix ceramics. Nowadays, the most widely used polycrystalline ceramics in dental practice are zirconium-dioxide ceramics while alumina-based restorations are gradually phased out [64]. The high resistance to fracturing of zirconium dioxide allows for the deployment of crowns with a minimal thicknesses of approximately 0.5 mm, thereby contributing to the biological benefit arising from the preservation of dental matter [65]. However, despite the high popularity in restorative dentistry, sensitive procedures of bonding and concerns about wear in antagonist teeth limit the use of zirconium dioxide crowns in pediatric dentistry [66, 67].

For indirect restoration materials, glass-matrix ceramics are usually preferred, as they were thought to be stronger and more reliable than their composite counterparts [31]. The elastic modulus of glass-ceramic is close to that of natural tooth enamel, with good aesthetic performance, stable long-term functionality and good bonding properties with tooth enamel. Therefore, glass-matrix ceramics are an ideal choice when the enamel bonding area is sufficient and children tolerate the procedures *involved* well. It should be noted that because the elastic modulus of glass-matrix ceramics is 3–5 times that of natural dentin, the inner part of the restoration in the coronal segment may apply an adverse wedge forces on the tooth tissue and can cause fracture of the tooth tissue [68].

However, with the development of resin-matrix ceramics in recent years, the physical and chemical properties of these materials have been increasingly improved. Resin-matrix ceramics [69] are ceramic materials with inorganic ceramic materials as the main component and resin matrix as the auxiliary component. Study has shown that the bending strength of resin-matrix ceramics can reach 100–200 MPa, and its elastic modulus is close to that of natural dentin [70]. Experiments have shown that 80% of failure modes of resin-matrix ceramic onlays are restorable, while most of the failure modes of glass-matrix ceramic onlays are accompanied by fracture of abutment teeth, and the failure mode is unrepairable [71, 72]. This is related to the fact that the elastic modulus of resin-matrix ceramics is close to that of natural dentin, which provides greater resilience and enables more stress absorption by deformation and produces well-balanced stress distribution [73]. Contrary to the mechanical failure of ceramic restorations, the main failure of composite restorations is related to biological complications. These include secondary caries formation and pulp complications [53]. Therefore, in our opinion, for children, resin-matrix ceramic restoration can well protect the thin walls and weak cusps of developing teeth, repair and maintain good oral and maxillofacial system function, and create favorable conditions for subsequent restoration if that becomes necessary. Thus, resin-matrix ceramic restoration constitutes a priority in indirect tooth restorations for pediatric patients.

4. Preformed crown restorations

4.1 Preformed metal crowns

The restoration of teeth with prefabricated metal crowns (PMCs) uses biocompatible bonding materials to bond a single prefabricated metal crowns to the teeth through certain shape adjustment [74, 75]. Humphrey first reported the application of PMCs in pediatric dentistry in the 1950s, and subsequently, Mink promoted their use for repairing large area defects in primary and permanent molars [76]. Because of their excellent performance, PMCs are considered to be the best method to repair decayed primary molars in caries-prone children [77, 78] (whether by using the Hall technique or conventional preparation techniques). Meanwhile, in cases of severely damaged FPMs in children, PMCs are a successful interim restorative option until a permanent restoration, usually of the full coverage type, can be placed later.

For molars with large area defects, the protection of residual tooth tissue should be considered in the design of the restoration scheme. PMC restorations can not only meet the requirements of tooth protection, but are also relatively easy to apply, and the costs are significantly lower than onlays or full crown restorations, making PMCs a widely accepted option. Together, PMCs can restore tooth shape and function, and compared to traditional crown restoration, PMCs enable better preservation of original tooth tissue, which conforms to the principle of tooth preservation. PMC restorations are recommended in the following cases [14, 75]: (1) Extensive caries or multi-surfaces caries where direct restoration cannot ensure long-term stability; (2) Developmental defects (*e.g.*, MIH, DI, AI), and or when failure of other available restorative materials is likely; (3) When transitional treatment such as apexification and revascularization is necessary; and (4). For intermediate restoration of fractured teeth.

However, there are also some deficiencies associated with the restoration of permanent molars with PMCs [25, 77, 79]. (1) The PMCs may become worn and perforated after a service life of about 2–5 years, and the require replacement; (2) Periodontal damage may occur when the crowns and cervical edges are poorly trimmed and polished; (3) Poor aesthetic effects, and allergic responses in some patients who do not tolerate Ni Cr alloy. Therefore, after the complete eruption of permanent teeth and stable occlusion, PMCs should be replaced with other more appropriate restoration methods.

4.2 Hall techniques (HT)

Although PMCs have shown predictive positive results in repairing FPMs, it is still impossible to avoid the use of dental burs and injections, which will cause discomfort in children [75]. The HT is a minimally invasive dental procedure that utilizes PMCs and glass ionomer cement to restore damaged primary molars [80, 81]. Moreover, HT not only significantly reduces the time spent in the dental chair, but also minimizes the level of anxiety associated with dental procedures [82]. Considering the above advantages, a trial has attempted to use HT to repair the first molars in children with extensive defects, and the outcome remains to be observed [83].

4.3 Preformed zirconia crowns

Considering the shortcomings of the PMCs mentioned above, two studies investigated to repair the FPMs by applying preformed zirconia crowns (PZCs) [84, 85]. Recently developed PZCs are a new treatment option that enables practitioners to provide excellent aesthetic effects, but mainly in primary dentition at first [86]. It has been reported that primary teeth restored with zirconia crowns may have a higher success rate and maintain better gingival health than PMCs [87].

Compared to a general restoration procedure which requires two treatment sessions, the main advantage of preformed crowns is to complete the restoration in one treatment process, without the need for impressions and manufacturing of prostheses. These are very important considerations for some patients with special needs, including the FPMs restoration under general anesthesia. Recently, a study compared the clinical and radiographic performance of PMCs and PZCs in restored FPMs. The result showed that PZCs could achieve the same or even better results than PMCs in relation to plaque accumulation and marginal integrity [85]. However, the time required for preparation and placement of the PZCs is longer than that of PMCs, which imposes higher requirements for dentists' operations [84].

5. Consideration of timing for indirect restoration

Currently, there are three perspectives on when young permanent teeth with large area defects can be repaired by using onlays or full crowns: (1) Immediate restoration; (2) Restoration after the eruption of the second permanent molar; (3) Restoration after reaching adulthood, *i.e.*, after the age of 18 years old. The main concerns of the first two views are that after the eruption of the FPMs, the attachment level of gingival is relatively high for a long time, the restorative crowns are short and the repair space is insufficient, which may lead to exposure of the restoration edge caused by subsequent gingival recession [62, 88]. However, advancements in bonding technology and materials, the retention requirements for onlays and crowns have been reduced, and the minimum thickness of prostheses is required to be 1–2 mm, thus reducing the need for restorative space. Together, an increasing number of posterior restorations are designed with an upper gingival edge, and the exposure of the restoration edge caused by gingival recession does not seem to affect the choice of the restoration time.

Research indicates that the main factors affecting the resistance of tooth tissue are marginal ridge, cusp ridge and interaxial dentin, while removal of dental pulp has a limited effect on the resistance of tooth tissue [89]. In children with molars undergone pulpotomy, the 5-year survival rate of teeth after direct restoration was only 66% [90]. A study by Morimoto *et al.* [91] showed that the restoration failure rate of vital pulp teeth was 80% lower than that of teeth after root canal treatment. Hence, for large area defects in vital first molars, timely and necessary crowns restoration is crucial after full communication with the parents. The key to treating such cases of extensive defects is whether children can tolerate with the treatment process, and the restoration design can meet reasonable retention resistance, prevent secondary caries, maintain the health of periodontal tissue, and not hinder the continued eruption of permanent teeth. Once a severely damaged tooth erupts, the gingival attachment drops to a normal level, fulfilling the conditions for conventional indirect restoration.

6. Deep caries excavation and restoration

Young FPMs with extensive defects caused by caries should avoid pulp exposure during the process of caries removal. There are typically three methods for removing decay: complete excavation, partial excavation and stepwise excavation. Compared to complete excavation that removes all caries, partial excavation removes part of the caries but leaves caries over the pulp while peripheral dentine is prepared to hard dentine, and subsequently completes the final restoration. Partial excavation can complete the final restoration in one dental appointment, and this significantly reduce the risk of pulp exposure, which is highly recommended for deep caries (*i.e.*, extending into pulpal third or quarter of the dentine) [92]. However, for stepwise excavation, the major part of carious dentin is removed during the first appointment, leaving caries over the pulp with the placement of a temporary restoration. After about 6–12 months, the remaining caries is removed and a final restoration is installed [93, 94].

Multiple studies have shown that compared to complete excavation, partial or stepwise excavation significantly reduces the risk of pulp exposure [95–97]. At the same time, one study compared the 5-year success rates of partial and stepwise excavation and found that the pulp exposure of partial excavation is much lower than that of stepwise excavation [98]. Two trials showed that after complete excavation, pulp complications and postoperative pain are higher than those associated with partial excavation [93, 96]. Moreover, a meta-analysis shows that the success rates of permanent restoration are similar for complete and incomplete excavation [99]. However, for stepwise excavation, the second caries removal increases the risk of pulp exposure, which is not conducive to pulp health [100]. Therefore, when dealing with large-scale defects in FPMs caused by caries, partial or stepwise excavation should be considered first.

7. Considerations for tooth extraction

A healthy and complete dental structure, due to the presence of resistance structures such as marginal ridges, cusp ridges, and oblique ridges, results in a relatively uniform distribution of chewing stress on sound crowns [101, 102]. Once the resistance structure is damaged, the stress often concentrates on the cervical of the tooth, generating unfavorable tensile stress on the dental tissue, and the thin-walled weak cusps are likely to fracture as a result. Study has shown that teeth with four-wall defects have a higher failure rate due to extensive loss of cervical dentin, regardless of whether post-core crowns restoration is used [103].

The traditional belief is that the first molar, as the key to occlusion, should not be extracted if not absolutely necessary [104]. However, numerous studies have shown that timely extraction of the first molar and orthodontic treatment not only avoid the uncertainty of restoration, but also ensures a healthy and continuous natural dentition, with good treatment outcomes [105]. Scholars from the University of Oslo extracted 84 FPMs from 24 children (average age 8.7 years old) affected by MIH, and found that the second permanent molars in all cases could naturally replace the FPMs. The exception were for 8 mandibular second permanent molars that required orthodontic-assisted extraction to the tooth position of the FPMs [106]. According to reports, the success rates of maxillary and mandibular arches vary, and most researchers believe that the probability of maxillary arch contact is 80–90%, while the probability of mandibular contact is about 50–60% [107, 108]. For patients who need orthodontic treatment and have a molar with large area defects, patients may lose the premolar during orthodontic treatment if the defective FPMs are reluctantly preserved. Therefore, under the condition that the tooth germ of the third molar appears and its shape and size are normal, the extraction of the first molar with a large area defect is also a plan worthy of serious consideration. The timing of tooth extraction and the need for symmetrical or balanced extraction can be referred to the literature of Royal College of Surgeons of England [109].

8. Conclusion

The current concept of minimally invasive prosthodontics emphasizes the preservation of tooth structure to maintain, the equilibrium of functional, biological and mechanical properties of a tooth [110, 111]. Generally speaking, the choice of options will mainly depend on the number of remaining healthy tooth structure [112, 113]. While considering other possible factors that affect young patients in particular, including their tolerance during dental procedures, oral hygiene and their need for future orthodontic corrections, treatment decision can be difficult.

In Class II molars that retain most of their structure, direct restorations are a good choice as long as the thickness of the remaining wall is appropriate (more than 2 mm wall thickness) and the functional tooth cusp is not affected [113, 114]. If rubber barriers can be placed for isolation to ensure good moisture control, composite restoration is a predictable choice with a high success rate [23–25]. However, consideration should be given to the change of structure, chemical and mechanical properties of MIH-affected teeth. If good moisture isolation cannot be achieved and hypomineralization cannot be completely removed, transitional restoration using glass ionomer is also an option.

When there is significant structural loss of tooth tissue, and the remaining wall thickness is less than 1 mm, and some cusps are lost, the most suitable option is indirect restoration [31]. The selection of materials is crucial in these indirect repairs. While, traditionally, porcelain has predominated in durability and biocompatibility [14], composites have gained ground due to their significant evolution in durability and performance in recent years [115]. Lately, the widespread CAD/CAM technology and superior mechanical properties of composite blocks have accelerated the use of indirect restorations [19]. It should be noted that the edge line of onlay is complex. Hence, the risk of secondary caries increases accordingly, which emphasizes the importance of oral hygiene for the patient.

In extreme cases of dental structure loss, exceeding two-thirds of the tooth, a crown is indicated for treatment. There is evidence supporting the use of PMCs in the restoration of teeth with severe defects [75]. However, for patients with high aesthetic requirements and good cooperation, PZC or full crown restoration can also be a preferred option, even though the procedures *involved* are more time-consuming and relatively expensive [6, 116].

In cases where the defect is extremely severe or the pulp is already infected, considering the long-term prognosis of the affected tooth and reducing the likelihood of repeated visits, scheduled tooth extraction is an option to be considered, especially for patients with the presence of third molars and subsequent orthodontic needs [117].

It is necessary to repair the teeth with large area defects immediately and reasonably. However, for children, due to their far from ideal cooperation, short clinical crowns, it is very difficult to repair the first molar with large area defects. Overall, advancements in materials and technology have expanded and improved treatment choices available for pediatric dentistry. Therefore, for pediatric patients with extensive first molar defects, clinical dentists need to consider and balance the condition of the affected tooth, provide appropriate pain control for the child, and weigh the advantages and disadvantages of various restoration methods to ultimately choose the most beneficial restoration method for the health of the affected tooth and the patient. It cannot be overemphasized that providing health guidance and continued oral education, regularly follow ups, will help children maintain long-term oral health.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

XYC, and KC—had the idea for the article. XYC, TFZ—performed the literature search and drafted the work. TFZ and KC—critically revised the work. All authors have read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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