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Adhesion to Enamel of Teeth Affected by Molar Incisor Hypomineralization: Literature Review

SUMMARY

Background/Aim: *Molar incisor hypomineralization (MIH) is a qualitative defect of systemic origin, affecting permanent first molars and often permanent incisors. The treatment modalities can include, amongst others, fissure sealants for prevention of dental caries and composite restorations. Both require adhesion to tooth structure. The aim of this study was to review the literature on the adhesion to enamel affected by MIH.* ***Material and Methods:*** *A search of PupMed/Medline, ResearchGate and Google Scholar was performed and limited between 2003, when the judgement criteria for MIH were set, and 2016. Thirty-three papers were considered relevant to the subject including five in vivo and six in vitro studies. Studies involving less than ten teeth were excluded.* ***Results:*** *A four-year clinical trial showed that the application of a total-etch 2-step adhesive system prior to sealant placement is superior to the etch-seal technique. Despite the high success rate of composite restorations shown in three clinical longitudinal studies, there are conflicting results over self-etch being superior to total etch adhesive systems. Pretreating the enamel surface, prior to the adhesive system, with fluoride preventive solutions could reduce the mikroleakage under orthodontic brackets. Three in vitro studies provide inconsistent data about NaOCl pretreating potentials to improve adhesion of composite restorations. Resin infiltration, prior to resin restorations, could improve the microhardness of defected enamel, which may lead to increased bond strength, especially in combination with NaOCl pretreatment.* ***Conclusions:*** *Adhesion to enamel affected by molar incisor hypomeralization is inferior compared to normal enamel. Sealants applied with the etch-bond-seal technique have greater retention than with the etch-seal technique. Further research is required to provide evidence of the effectiveness of the adhesive system and pretreatment to achieve optimal bonding to MIH.*

Key words: Molar Incisor Hypomineralization, Adhesion, Etching, Bonding, Treatment, Management

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Introduction

Molar incisor hypomineralization is defined as a dental defect of systemic origin, that affects 1 to 4 permanent first molars, and frequently is associated with permanent incisors[1]. Many terms have been used in the past, such as "cheese molars" and "idiopathic hypomineralization of the enamel of the first molars"[2]. The term of MIH was agreed in 2003 at the annual conference of European Academy of Paediatric Dentistry in Athens[3]. The judgement criteria for MIH were also set at the same conference[3]. The clinical appearance includes demarcated opacities, varying in color from white to yellow or brown[4]. These opacities are located on the occlusal and buccal surface of the tooth and ranging in size[4], while the thickness of the enamel is normal. In severe cases, post eruptive breakdown of the enamel can occur due to masticatory forces[4]. These teeth are more prone to caries, more sensitive to external stimuli and therefore may be more difficult to anaesthetize[4]. The etiology is yet unknown, but has been associated with different hypotheses including genetics, medical problems during pregnancy and postnatal medical problems[4]. The prevalence has a wide variation from 2.4 to 40.2% all over the world and been reported to be increasing[5]. The treatment approaches are prevention of dental caries and enamel breakdown, restoration or extraction, depending on the severity of the defect, the dental age of the patient, the social background and expectations of the child and their parents[4]. Prevention can include fissure sealants and restoration can include composite fillings. Both require adhesion to tooth structure. Bonding of orthodontic brackets also requires adhesion. In 1955, etching the enamel with an acid was proposed in order to improve adhesion[6]. There are three etching patterns in the enamel, known as Type I, II and III. In type I there is dissolution of the prisms core, whereas in type II the periphery of the prisms is dissolved[7]. In type III deep etching is not achieved and only the crystals around the prisms are partially removed[7]. Type I and type II are considered to be effective etching patterns that can provide adequate adhesion, whereas type III is thought to be undesirable pattern[7]. Acid etching enamel, affected by MIH, may produce a surface matching a type III pattern[7].

Understanding the formation of the MIH enamel and its characteristics gives valuable information about the structure available for bonding. The enamel is formed through a process called amelogenesis and occurs in two phases, secretion and maturation[8]. In the first phase, ameloblasts deposit the organic matrix of the enamel in layers, which are going to form the full thickness of the future enamel[8]. In the second phase ions are transported by the ameloblasts to mineralize the enamel[8]. Any alterations in this stage will affect its quality[9]. MIH is a qualitative defect of the enamel. Therefore, an alteration has occurred in the maturation phase, affecting the ameloblasts[10]. MIH affected enamel is histologically presented with less distinct prism sheaths compared to normal enamel[11]. The crystals are disorganized[11], loosely packed[12] with enlarged interprismatic space. There is also a higher carbonate content[13], decreased mineral content and increased amounts of proteins[14]. The amount and the quality of the protein content depend on the severity of the defect. This high protein content contributes to lower mechanical properties in comparison with normal enamel[15]. It was shown in one study that the hardness and the modulous of elasticity were reduced by 80%[15]. MIH enamel also presents greater porosity and lower mechanical resistance[16]. These structural weaknesses could explain the post eruption breakdown[17] and the greater dental abrasion[18], leaving the enamel rough and more susceptible to caries[5].

The aim of this paper is to review the literature concerning the adhesion to enamel affected by MIH.

Material and Methods

A search of Pubmed/Medline, ReasearchGate and Google Scholar was performed and limited between 2003, when the judgement criteria for MIH were set, and December 2016. The used keywords were ‘molar incisor hypomineralization’, ‘adhesion’, ‘etching’, ‘bonding’ and ‘treatment management’. The number of papers identified were 503, including duplicates. After assessing their abstracts, studies involving less than ten teeth and in language other than English were excluded. Finally, thirty-three papers were included (5 clinical trials, 6 in vitro studies, 3 systematic reviews and 1 policy document and 18 literature reviews) and their full text was then read. Only two papers, the review by Mathu-Muju and Wright[19] and the review by Sapir, were not assessed full text, as their content was not available even after emailing the authors. The reference list of each of these papers was also assessed to eliminate the exclusion of any additional relevant paper. Table 1. shows the list of the five clinical trials. Table 2. shows the list of the six in vitro studies.

Table 1. Clinical trials

Title, Authors	Methods	Results
Lygidakis et al. 2003[20]	• prospective study • 52 molar teeth • evaluation after 7 days, 12, 24, 36, 48 months • according to Ryge criteria	• 100% success of composite restorations after 4 years
Mejáre et al. 2005[21]	• retrospective study • 76 individuals with MIH • Ryge criteria • evaluation after a mean period of 5 years	• 85.3% success of composite restorations after a mean period of 5 years • high need for retreatment
Kotsanos et al. 2005[22]	• retrospective study • 72 children (36 MIH, 36 normal enamel) • Ryge criteria • evaluation after a mean period of 4.5 years	• 74,4% success of composite restorations after a mean period of 4.5 years • high need for retreatment
Lygidakis et al. 2009[23]	• prospective study • 54 children with at least 2 contra-lateral FPMs with MIH • 4 years split mouth study • criteria: sealed- partly sealed- unsealed	• significantly greater retention when applying total-etch 2-step adhesive system prior to sealant
de Souza et al. 2016[24]	• prospective study • 41teeth-2 groups (self-etch and total-etch) • USPHS criteria • evaluation after 1,6, 12 and 18 months	there was no significant difference between total etch and self-etch adhesive systems

Table 2. In vitro studies

Title, Authors	Methods	Results
William et al. 2006[25]	• 55 teeth were tested for microshear bond strength (44 specimens of control enamel and 45 of hypomineralized enamel)- Instron testing machine • 5 teeth(8 specimens control enamel and 8 hypomineralized) under SEM to study etching patterns, 3M and Kuraray used	• inferior bonding to MIH affected enamel compared to normal • no significant difference between total etch and self-etch systems for MIH affected enamel
Gandhi et al. 2012[26]	• 31 teeth organized in three groups (control: etch and sealant, group 1: 5% NaOCl-etch-seal, group 2: 5% NaOCl-seal) • studied under SEM	• no difference between etch-seal and bleach-etch-seal technique for MIH affected enamel
Moosavi et al. 2013[27]	• 75 teeth, 5 groups (1:control, 2: demineralized/control with acid etching, 3: 5% NaOCl for 1 min after acid etching, 4: self-etch primer, 5: 2% NaF for 4 min before acid etching • cariogenic solution used • microleakage was tested under stereomicroscope	• self etching primer significantly increased microleakage at the adhesive bracket interface • 2% NaF gel for 4min significantly reduced microleakage at the enamel adhesive interface
Crombie et al. 2014[28]	• 21 teeth, 3 groups • (1: HCl etch-ethanol-infiltrant resin, 2: 0.95% NaOCl – Icon, 3: HCl etch-0.95% NaOCl-ethanol- resin) • Vickers microhardness test • SEM	• failure of NaOCl to produce significantly improved results • caries infiltrant materials can penetrate and increase the hardness of MIH enamel, but unpredictably
Chay et al. 2014[29]	• 105 specimens-5 groups (1: normal, 2: hypomineralized, 3: hypomineralized pretreated with Icon, 4: hypomineralized pretreated with 5.25% NaOCl and Icon, 5: hypomineralized pretreated with 5.25% NaOCl • SEM • MSBS testing (Mecmesin testing machine)	• pretreatment with 5,25% NaOCl significantly increased the mean microshear bond strength values of composite restorations
Shahabi et al. 2014[30]	• 100 teeth-5 groups (1: 30 sec acid etch, 2: 120 sec acid etch, 3: laser-acid etch, 4: self etch primer, 5: APF- acid etch) • cariogenic solution • SBS test (Instron universal testing machine) • stereomicroscope	• self-etch primers produced significantly lower shear bond strength at the enamel-adhesive interface

Results

A) Etching and pretreatment

There is only one in vitro study about etching. An in vitro study by William et al. has evaluated the etching pattern, produced by the application of 35% phosphoric acid etch and self-etching primer. The enamel of 16 specimens, including control and hypomineralized, was sectioned perpendicular and parallel to the enamel rods, etched and then examined under Scanning Electron Microscope (SEM). The perpendicular sectioned group showed preferential dissolution of rod peripheries for phosphoric acid, but not in a uniform way as in control group[25]. There was loss of enamel between the rods, but the intercrystal porosity was limited[25]. The parallel sectioned group showed partial removal of the intra rod enamel and minimal increase of the area surface[25]. The formation of microtags, important for bonding, is limited and the large interprismatic space may retain moisture and weaken the whole structure, allowing crack propagation[25]. The group treated with self-etching primer showed uneven preferential dissolution of the peripheral inter-rod areas, producing a deeper pattern than in control enamel. It appeared that etching affects more the porous hypomineralized enamel and may expose its high organic part.

There are four in vitro studies assessing the treatment outcome of NaOCl, when applied prior to the adhesive system, to improve adhesion of composite restorations. One of them uses artificially demineralized enamel and, therefore, it is not going to be taken into consideration at this point. The first study in 2012 by Gandhi et al. investigates the tag formation between the conventional technique of ‘etch and seal’ and the incorporation of 2.5% NaOCl with or without etching[26]. There was no significant difference between the etch-seal and the bleach-etch-seal technique and no benefit from using only NaOCl without etching[26]. This study also showed that poor sealant tag was obtained regardless the treatment. The second in vitro study in 2014 by Crombie et al. assessed the resin infiltration to MIH enamel with the conventional technique and with incorporation of 0.95% NaOCl, before and after etching with HCl[28]. This study concluded that NaOCl failed to produce significantly improved results for deeper resin penetration[28]. In the vitro study by Chay et al.[29], there was comparison between various enamel pretreatments to improve the adhesion of resin composite to hypomineralized enamel. After microshear bond strength testing, the highest bond strength was associated with the 5.25% NaOCl pretreatment followed by resin infiltration[29].

B) Sealants and adhesion

There is only one in vivo study about sealants. The etch-seal technique, as mentioned above, was shown to be insufficient for MIH affected enamel, because poor sealant tags were obtained[26]. The introduction of a new technique, known as etch-bond-seal, has shown significantly better results[23]. In a four-year split mouth study by Lygidakis et al., the two techniques were tested. 54 children with at least two MIH affected first permanent molars on opposite sides of the mouth, participated in this study. The teeth had occlusal opacities with no enamel breakdown. The color of the opacity, hence the severity, was not mentioned. One side received one treatment assigned randomly, while the opposite side received the other. It was concluded that significantly greater retention of sealants was achieved by applying total-etch 2-step adhesive system prior to sealant placement[23] rather than the etch-seal technique. This may be due to lower viscosity of these adhesives and therefore their ability to penetrate deeper in the enamel[23].

There is only one in vitro and only one in vivo about the adhesion system. The in vitro studied by William et al. found no significant difference between the 'etch and rinse' and self-etch adhesives systems[25]. Both systems have been shown to have inferior bond strength to MIH affected enamel compared to the normal one. High frequency of cohesive fractures within the enamel was also noted[25]. In this study teeth with yellow brown opacities and with posteruptive breakdown were included, without them receiving cavity preparation. The same study also suggested that there might be some indication for self-etching systems[25]. A recent in vivo study by Souza et al., involving 41 teeth with conservative cavity design showed no difference between the two adhesive systems[24].

C) Composite restorations and Bonding of orthodontic brackets

There are three longitudinal in vivo studies, one prospective and two retrospectives, and one in vitro evaluating the success rate of composite restorations. The four-year prospective study by Lygidakis et al. showed 100% success[20]. The two retrospective studies by Kotsanos et al.[22] and Mejàre et al.[21] showed high success rates 74.4% and 85.3% respectively, and high need for retreatment up to 11 times. The first one states clearly the cavity design, which is the removing of all defective enamel. The other two studies provide no information about the exact procedure followed and the materials used. The in vitro study by William et al.[25], as mentioned above, showed high frequency of cohesive failures within the enamel, probably due to the presence of defected enamel.

There are not any studies investigating the bonding of orthodontic brackets to MIH affected enamel. Two in vitro studies have used cariogenic solution to mimic hypomineralized enamel and tested the microleakage and shear bond strength[27,30]. It was shown that pretreating the enamel with 2% sodium fluoride for 4 minutes, before etching, could significantly reduce the microleakage under orthodontic brackets[27]. The highest microshear bond strength was achieved after the application of acidulated phosphate fluoride, but the difference was not statistically significant[30].

Discussion

Acid etching enamel, affected by MIH, may produce a surface matching a type III pattern[7], as William et al. has showed for 35% phosphoric acid. MIH enamel differs from normal enamel structurally due its high organic content. Therefore, it is more susceptible to caries and post eruption breakdown. Consequently, etching with phosphoric acid will not produce the same pattern as with normal enamel. The persistence of carbonate in MIH affected enamel may decrease the solubility of the hydroxyapatite crystals[31]. Extraction of these teeth is required to study the etching pattern under scanning electron microscope. The availability, hence, of these teeth is limited. Usually molars, severely affected and with breakdown, are the ones extracted. These kinds of molars were used in the only in vitro study that has examined and compared the etching pattern produced by 35% phosphoric acid and self-etch primer on MIH enamel. Although a more favorable etching pattern was produced with self-etching primer compared to normal enamel, it was not enough to provide higher bond strength. There was no cavity preparation and no removal of defective enamel. The exact etching time was not specified and whether the manufacturer's instructions were followed was not mentioned. Further studies are needed to evaluate the etching pattern produced by phosphoric acid and self-etch primers applied for specific times on enamel without breakdown. Then the results, after increasing or decreasing the application time, can be compared. The outcomes could give essential information to the clinician when providing sealants or bonding orthodontic brackets.

In the effort to improve this irregular etching pattern, a pretreatment of the enamel has been suggested[19]. The pretreatment with NaOCl could theoretically remove the entrapped proteins from MIH enamel. Nevertheless, the studies so far have contradicting results, but cannot be compared with each other, because dissimilar materials and methods were used. These studies used scanning electron microscope. The study by Gandhi et al.[26] was qualitative and bond strength was not measured. The study by Crombie et al.[28] used Vickers hardness test and the one by Chay et al.[29] used microshear bond strength test. Gandhi et al.[26] showed poor tag formation regardless the pretreatment, which enhances the results by William et al.[25] of inferior adhesion compared to normal enamel. Crombie et al.[28] showed failure of NaOCl to promote deeper penetration of resin infiltrant materials. The study by Chay et al.[29] has showed that NaOCl pretreatment with or without resin infiltration could significantly promote adhesion. NaOCl potentials were shadowed by the excellent performance of the total-etch 2-step adhesives before sealant placement. The different concentration percentage of NaOCl used in each study might be an important aspect. No conclusion can be drawn, as further reasearch is required. Further high quality in vivo studies could enlighten these potentials and the potentials of resin infiltration, which has been used so far to aesthetically improve MIH incisors.

This irregular etching pattern mentioned above is certainly affecting the application of sealants, which are meant to protect teeth from caries. Lygidakis et al.[23] showed significantly increased retention of sealants with the application of total-etch 2-step adhesive system prior to sealant placement. It is important mentioning that it was a split mouth study minimizing this way the risks of bias, although the color of the opacities, hence the severity, was not mentioned.

As far as adhesive systems are concerned, studies give insufficient results. Choosing the adhesive system is difficult as inferior bond is achieved to teeth affected by MIH. This is supported by the in vivo studies of Kotsanos et al.[22] and Mejàre at al.[21] that showed the high need for retreatment for the MIH groups. William et al.[25] suggest that there may be an indication for the self-etching systems, as they could theoretically provide better results. The omission of etching and rinsing will eliminate the presence of residual water, which can compromise the bonding[4]. The lower viscosity will allow the adhesive to penetrate deeper in the enamel, increasing this way the total surface available for bonding[4]. In addition, some of these systems have the ability to bond both micromechanically and chemically to hydroxyapatite and can also release fluoride along with their antibacterial properties[32]. Therefore, they are associated with less postoperative sensitivity, which is very important when restoring MIH affected teeth as they might already be too sensitive[33]. Nevertheless, there is no study to prove the superiority of these systems. It is worth mentioning that the study by Lygidakis et al.[20], that showed 100% success of composite restoration, used total-etch 2-step adhesive system[20]. Further studies of high quality are needed to evaluate and compare the performance of these two adhesive systems.

If restorative treatment of the MIH affected teeth is required, composite restorations will usually be the first choice, when one or two surfaces are involved, the defect is well defined with no cuspal involvement and there are supragingival margins[34]. Stainless steel crowns are not aesthetic and far more invasive than composite fillings. Composite restorations have high success rate on MIH teeth, but there is also high need for retreatment. The cavity design is of high importance. There are two potential cavity designs, removing all defective enamel[19] and removing only the porous enamel[34]. The first one involves excessive tooth removal, but provides sound enamel for bonding[4]. The second one is more conservative, but there is high risk of unstable bonding[4]. The extent of the defect could theoretically affect the cavity design. Smaller defects could be approached with removing all defective enamel and extensive defects conservatively in the effort to preserve as much enamel as possible. Placing composite restorations might though require the removal of all discolored hypomineralized enamel[20]. This is supported by the high rate of cohesive fractures within the enamel found by William et al.[25], where defective enamel was not removed. In addition, Lydidakis et al.[20] showed 100% success of composites after removing all defective enamel, although there is not any information about blinding of the operator. The studies by Kotsanos et al.[22] and Mejare et al.[21] provided no information about the cavity design and the used materials. Further studies with defined cavity design and treatment procedure should be conducted.

Orthodontic treatment of children with MIH affected enamel appears to be challenging. Due to the inferior adhesion to these teeth, there may be increased treatment times or even a poorer orthodontic outcome. These teeth could theoretically be benefited from application of preventive solutions, especially before bonding of orthodontic brackets, which can promote further demineralization. The studies so far in this area use cariogenic solutions to mimic the hypomineralization, producing enamel that is different to the rich in protein MIH enamel. Treating the MIH affected enamel with fluoride varnish could theoretically enhance remineralization, especially when there is complain to external stimuli or spontaneous hypersensitivity[4]. The potential of these solutions should be further studied.

Conclusions

Adhesion to enamel affected by molar incisor hypomeralization is inferior compared to normal enamel. Acid etching this enamel can cause more enamel loss and exposure of its organic content, leaving an undesirable etching pattern for bonding. The application of total-etch 2-step adhesive system can increase the retention of sealants. There is no evidence to support that self-etching adhesive systems are more effective than total etch systems when placing composite restorations. Deproteinazation of the protein enriched MIH enamel with NaOCl pretreatment could theoretically enhance adhesion. Further prospective randomized clinical trials are required to provide evidence based solutions to the clinician to treat effectively teeth affected by molar incisor hypomineralization.

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