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REVIEW

Cavity Bases Revisited

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Objective: The aim of this paper was to review the current literature on cavity bases while focusing on the role of zinc oxide eugenol (ZOE) and resin-modified glass ionomers (RMGI) as cavity bases.

Materials and Methods: A thorough literature search between 1970 and 2020 was done using Scopus, PubMed, and Google Scholar databases. The keywords of the search strategy were as below: cavity liners and bases, pulp protection, zinc oxide eugenol, and resin-modified glass ionomer. No specific inclusion or exclusion criteria were applied as to what articles would be included in this review.

Conclusion: This review emphasizes that the available literature provides very little evidence to support the routine use of a base under amalgam or composite restorations. This review favors the adoption of "no more lining or bases" in shallow and moderate cavity preparations. However, an exception might be a "protective base" of RMGI following the application of calcium hydroxide (CH) liners in deep cavities. Bonded RMGIs are suitable cavity base materials and should always replace zinc oxide eugenol bases in daily practice.

Keywords: bases, liners, pulp protection, resin-modified glass ionomer, zinc oxide eugenol

Introduction

Traditionally, liners and bases have long been recommended under restorations, particularly when a substantial removal of dentin occurs during the cavity preparation process. Many dentists have gained the impression that a cavity base and/or a liner is necessary to protect the pulp from the toxic effects of dental materials.[1–5] However, many studies have confirmed that the pulpal inflammation under restorations is due primarily to the leakage of microorganisms rather than irritation from restorative materials.[6] Thus, there is an increasing emphasis on the integrity of the interface between the restorative material and prepared tooth. Dental manufacturers constantly introduce "new and improved" versions of existing products. The vast number of available choices makes it difficult for the general practitioner to select proper materials and make suitable clinical decisions.[7] Nowadays, The use of liners and bases has become a topic of considerable controversy with a growing number of clinicians and investigators challenging their use.[6,8,9]

Definition of a Base

Marzouk et al[10] defined cavity bases as insulating materials that can be used directly on certain areas of the dentinal parts of the preparation. Additionally, they may also be used indirectly as supporting, retaining modes for sub-bases (liners). In 1994, The Journal of Operative Dentistry published a letter submitted by Summit[11] in which he proposed a definition for a cavity base as a dentin

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replacement material used for bulk replacement of missing tooth structure to allow the material in the restoration to have less bulk, or for blocking out undercuts for indirect restorations. They added that the material should have adequate strength and modulus of elasticity. Later on, McCoy[12] submitted a letter to the same journal in which he made changes to the original definition and structure (based on the feedback from Operative Dentistry readers) previously made by Summitt. McCoy stated that a cavity base is a replacement material for missing dentinal tooth structure, used for bulk buildup and/or for blocking out undercuts. Hilton[13] also defined a cavity base as a dentin replacement, either for bulk buildup and/or blocking out undercuts for indirect restorations. Likewise, Van Noort and Barbour[14] used the same definition as a dentine replacement used to minimize the bulk of the restorative or block out undercuts. Moreover, Qualtrough et al[15] defined a cavity base as a material, used to base a prepared cavity before the insertion of a permanent restoration, to protect the pulp and act as a dentine replacement. Powers et al[16] classified bases into two categories. The first is for high-strength bases used to provide mechanical support for a restoration and thermal protection for the pulp. These include glass ionomers, RMGI, and polymer-reinforced ZOE cements. The second category includes low-strength bases which is also known as cavity liners (should be distinguished from cavity liner suspensions).[17] Ritter et al[18] pointed out that the concept of cavity bases beneath amalgam and resin-composite restorations is different. On one hand, they described traditional bases as materials used in layers (thicker than liners) beneath metallic permanent restorations to provide for mechanical, chemical, and thermal protection of the pulp. On the other hand, they added that composite resin materials are thermal insulators, and; hence, do not require the same pulp protection as in amalgam restorations. Similarly, Banerjee and Watson[19] state that the terms should be carefully defined to avoid confusion between "liners" and "bases" which were coined when amalgam was the only material of choice to restore cavities and terms currently used in the modern era of minimally invasive dentistry.

It is obvious that the function and definition of a cavity base have evolved and changed from materials used to provide thermal, mechanical, and electrical insulation under amalgam restorations to materials almost exclusively used as internal buildups (at the pulpal and/or axial walls) and to block undercuts mainly in preparations for indirect inlays and onlays.[20]

Bases Under Amalgam

The use of bases under amalgam is a topic of considerable controversy. Previously, cavity bases were recommended under amalgam restorations placed in moderate (middle third of dentine) and deep cavities (close to the pulp).[5,20,21] However, their use is currently limited to deep cavities where a CH liner is placed.[4,17,22]

There is a common misconception that it is necessary to place a base beneath any metallic restoration to protect the pulp from thermal shock and pain. Little et al,[22] assessed the heat transfer through four lining materials (Kalzino, Vitrebond, Scotchbond 1, Dycal) and dentine and related their findings to the temperature exposures that may be experienced in the oral environment. They concluded that only extreme temperatures applied for long times would be harmful to the pulp. As these are unlikely to occur in vivo, the insulating property of a cavity lining material is not of great significance and therefore, other criteria for selecting a base or a liner should be applied.

Bases Under Composites

The practice of placing a base under resin composite restorations seems to be extrapolated from the principals of cavity preparation and pulp protection under amalgam restorations. There is scarce evidence available on the advantages of a base under resin-based composites, except in deep cavities.[7,23-26] Chailert et al[27] compared the internal adaptation of composite restorations without lining using a two-step etch and rinse and a two-step self-etch adhesives to restorations with a RMGI base. The study reported that composite restorations with no lining had the best internal adaptation, which did not depend on the type of adhesive. Peliz et al[28] reported that using adhesive agents alone provides superior internal adaptation at the dentin-restoration interface than does CH or RMGI. Dionysopoulos and Koliniotou-Koumpia[29] evaluated the interfacial microgaps between different materials (Dycal, Clearfil Tri-S Bond, Vitrebond) and dentin after polymerization of the composite restorations, using SEM. The results of their study showed that the microgaps between the bonding agent and dentine was significantly smaller than that observed between the Vitrebond-dentine and the Dycal-dentine. Azevedo et al[30] reported that the use of RMGI lining does not affect the bond strength and gap formation at the lateral walls of a Class I type cavity.

The benefit of placing a GI base under resin composite restorations has been investigated. Banomyong et al[31] investigated the effect of placing a RMGI liner on the quality of posterior resin composite restorations, bonded with a two-step etch and rinse or self-etching adhesive, at 1 year and concluded that the benefit of placing a RMGI liner beneath a posterior resin composite restoration is questionable. A long-term clinical study by van de Sande et al[32] investigated the influence of GI base on the survival of posterior composite restorations. They reported that the presence of a GI base did not affect the survival of resin-composite restorations. Opdam et al[33] reported that posterior composite restorations placed in combination with GI linings showed more fractures than restorations placed only using an etch and rinse adhesive. They concluded that posterior composites without linings may remain in clinical service longer than those with linings. Postoperative sensitivity is an issue that might concern the dentist when deciding whether to use a cavity base or not. There is evidence that no difference exists in post-operative sensitivity when a resin composite is "bonded" or "based".[34,35] The findings of a 2016 Cochrane review state that there is inconsistent, low-quality evidence regarding the difference in postoperative hypersensitivity after placing a dental cavity liner under Class I and Class II posterior resin-based composite restorations in permanent posterior teeth in adults or children 15 years or older. Furthermore, no evidence demonstrates a difference in the longevity of restorations placed with or without dental cavity liners.[36] Therefore, with the fact that resin composite is a poor thermal conductor, it might be stated that the application of cavity a base under a resin composite restoration should be limited to cases where a pulp capping agent (Calcium hydroxide) has been applied.[37]

Teaching Liners and Bases

Survey studies report an inconsistent implementation of pulp protection protocols among general dentists, with a strong indication that they consider lining and/or basing procedures as an essential part of the restorative process even if not supported by scientific evidence.[38–42] Dentists most likely follow the protocol they learned in dental schools. However, surveys among dental schools report variations in teaching the selection of liners, base materials, and lining techniques. Such inconsistency in teaching might be a reflection of the lack of consensus in the research community on the appropriate pulp protection protocols under restorative materials. Kanzow et al[43] investigated the teaching of operative procedures and techniques for posterior composite resin restorations in 33 dental schools in Austria, Germany, and Switzerland. None of the responding schools reported teaching the mandatory use of liners or bases when placing posterior composites in shallow or moderately deep cavities. In the management of deep cavities, the majority of schools (58%) reported teaching the mandatory placement of a liner. Another study that investigated the teaching and operative techniques of posterior composite restorations in 15 dental schools in Oceania (Australia, New Zealand, Fiji, and Papua New Guinea) reported such inconsistencies. In deep cavities, the combined use of CH and GI cement before composite placement was taught by most schools (67%). The use of GI cement alone as a base was mostly used in moderate (87%) and shallow cavities [n=9; (60%)]; respectively. Nine respondents (60%) taught the use of the 'total-etch method in shallow and moderate cavities'.[44] Similar inconsistencies were reported in a study that investigated the current teaching of posterior composite resin restorations to undergraduate dental students in Ireland and the United Kingdom (UK). It found variations between dental schools in the teaching of the indications for liners and bases. Only three schools of the 18 respondents teach using no liner or base in deep cavities. Two-thirds taught a GI base in the moderate cavity while one third taught not to use a liner or base. All the respondent schools taught their students not to use a liner or base in shallow cavities.[45]

Types of Bases

Zinc Oxide Eugenol

Zinc oxide eugenol (ZOE) is the traditional base for amalgam restorations. ISO 3107:2011 (Which has replaced ISO 3107:2004 that listed four types) describes two types of ZOE: Type I for temporary cementation and Type II for bases and temporary restorations. Type I cements are used for short term luting (1–6 weeks). Type II cements are used for the interim period (few weeks to few months). ZOE base materials have several advantages. In general, ZOE bases are widely used for their sedative effects on pulp pain.[46] Hence, ZOE is considered an effective option for a dental cavity base, especially for deep cavities in teeth with reversible pulpitis.[47] Investigations of the antibacterial effects of different restorative dental materials reported that ZOE (IRM) had a strong antibacterial effect against different microbial species including *Streptococcus mutans*.[48,49] However, IRM has poor sealing properties[50] and has been reported to display higher microleakage values than glass ionomers.[51]

The unmodified ZOE has poor mechanical properties. This, combined with the high solubility, makes it unsuitable as a cavity base or liner material. Modified ZOE cements were introduced to improve the mechanical properties and reduce the solubility of the regular unmodified ZOE. The first of these modifications take the form of resins (20% particulated polymethyl methacrylate) added to the powder and/or the liquid. The added resin improves compressive strength sufficiently high for the material to be used as a cavity base or liner. The material can also be used as a temporary filling material since it is less soluble in the oral cavity than the unmodified cements. The other type of modified ZOE substitutes o-ethoxybenzoic acid (EBA) for part of the eugenol liquid. The addition of EBA allows for the use of very high powder-to-liquid ratios which, per se, increases the strength of the set cement. Of the EBA cements now utilized, the zinc oxide usually contains 20–30% aluminum oxide. These modifications improve the compressive strength and reduce the solubility significantly, which in turn, makes EBA cements suitable for use as liners and temporary filling materials.[14,16,52]

Contradictory literature reports exist on the influence of ZOE bases on composite restorations. While some studies have reported that ZOE bases are unsuitable base materials beneath composites, due to the polymerization inhibition, degradation of the interfacial properties and lack of adhesion between the base material and the resin,[53–55] other studies contradict this common belief.[47,56,57] Lingard et al[53] investigated the effects of four lining materials (Dycal, Procal, Cavitec, Poly F) on two chemically-activated composites (Adaptic and Concise). The study evaluated the surface roughness, hardness, and color both with and without a bonding agent between the restorative material and the liner. The ZOE base material (Cavitec) seemed to have an adverse effect on the composites tested for the tested parameters. Another study by Marshall et al[54] examined the effects of five base materials on the hardness of three composite resins (two chemically cured composites and one light-cured composite). The bases included a ZOE (Kalzinol) and an EBA (Stailine Super EBA). Both base materials caused a reduction in the hardness of each composite. Grajower et al[55] investigated the interface between a chemically activated composite resin (Adaptic) and several pulp insulating materials using a scanning electron microscope. The study concluded that ZOE is incompatible with the tested resin composite. It could be noted that the aforementioned studies conducted their investigations using chemically activated composites and reported that they were affected by ZOE bases. More recent publications reported no or minimal effect of ZOE bases on the polymerization light-cured composites Itskovich et al[56] evaluated the effect of two base materials (IRM and Fuji IX) on five composite restoration materials. They reported that, related to microhardness, both ZOE (IRM) and GI (Fuji IX) bases can be used safely as bases under composite restorations. Moreover, He et al[47] examined the elastic modulus and microhardness of resin composites placed above the ZOE base (IRM). They concluded that the ZOE affects the composite microhardness and elastic modulus to a distance of only 100 microns from the interface, and so it can be a suitable material to be used under composites. This was supported also by the work of Anastasiadis et al[57] who evaluated the effect of four cavity base materials (Equia-fil, Angelus white MTA, Biodentin, and IRM) on the surface properties (morphology, roughness, microhardness, composition) and bond strength to a composite. They also reported that resin bonding to IRM is a reliable method when etch and rinse procedures are applied. Alternatively, self-etch adhesives with mild pH may be used, but with less bonding reliability.

However, although ZOE cements have been used for many years as cavity bases, their use has diminished in recent years with the introduction of materials that release fluoride and adhere to dentin. As the literature supports the need to seal the interface between dentin and the restorative material. It is suggested that RMGI should be favored when a "replacement" or substitute base for the protective dentin is required.[22]

Resin-Modified Glass Ionomer

RMGI was developed in an attempt to overcome some of the drawbacks of the conventional GIC (low early strength and moisture sensitivity during setting). The powder in RMGI is predominantly composed of fluoro-aluminosilicate glasses and the liquid consists of three principal ingredients: polyacrylic acid which reacts with the ion-leachable glass to form the setting cement; Water, which is an essential component necessary for ionization of the acid component so that the acid-base reaction can take place, and finally a water-soluble methacrylate monomer, such as hydroxyethyl methacrylate (HEMA). The setting involves both polymerization and acid-base reaction. The setting initially occurs by polymerization (light-cured or chemically cured) of the methacrylate groups giving it high early strength. Then an acid-base reaction follows, thereby completing the setting reaction and giving the cement its final strength.[58]

The placement of a cavity liner or base of low-viscosity /low-elastic moduli materials such as RMGIs and flowable composites has been suggested to create a stress-absorbing layer.[59,60] This layer increases the strain capacity and reduces the stresses at the adhesive interface.[59,61] These materials were also suggested as an attempt to provide a volumetric reduction of resin composite.[60] The benefit of these techniques in reducing polymerization shrinkage and stress-relieving remains controversial. On one hand, the polymerization shrinkage for RMGIs found in recent studies contradicts the notion that RMGIs have less polymerization shrinkage than that of composite resin.[62,63] On the other hand, Oliveira et al[64] reported that cavity liners and bases of lower elastic modulus were unable to compensate for the polymerization shrinkage stress of the restorative resin composite. Nguyen et al[65] reported that the use of liners and bases of low elastic modulus results in the same degree of cuspal deflection as restorations with only composite resins.

The current protocols for pulp protection impose a protective RMGI base wherever CH liners are indicated. This is to compensate for the drawbacks CH liners, that is, if microleakage occurs at the interface between the restoration and the tooth, the RMGI will act as an insoluble barrier against bacterial penetration into the deeper portions of the cavity preparation. RMGI is usually applied after conditioning the tooth with polyacrylic acid (10–25%). However, dentin etched with 35% phosphoric acid for 15 seconds before the RMGI application has been reported to improve adhesion between the material and dentin.[66]

The adhesion of RMGI cements to dentin can be improved by the application of an adhesive system promoting adhesion between the resin component and dentin by forming a hybrid layer. Imbery et al[67] evaluated the effect of six surface treatments on the shear bond strength of three RMGIs to dentin. They reported that all three RMGIs obtained their highest bond strengths when the two-step etch and rinse adhesive agent (Optibond Solo Plus) was applied after etching dentin with 37% phosphoric acid for 10 seconds. Besnault et al[68] investigated the effect of seven self-etch bonding systems on the shear bond strength of RMGI (Fuji II LC) to dentin and compared it with a cavity conditioner. Compared to the cavity conditioner, the application of self-etching adhesives improved the dentin shear bond strengths of Fuji II LC.

Nevertheless, when RMGI cements are bonded to dentin with an adhesive system; the fluoride release properties of the ionomer cement are interfered with. Miranda et al[69] investigated if the presence of the adhesive, being part of the hybrid layer composition, interfered with the fluoride released to tooth tissues. Their results showed that the use of a dental adhesive significantly decreased the fluoride release of RMGI (Vitremer). Similar results were reported by other studies.[70,71] However, taking into consideration that increased adhesion and reduced microleakage provides better benefits clinically than the fluoride release per se. Geerts et al[72] evaluated the marginal sealing ability of different RMGI restorations (Fuji II LC): RMGI was placed on the dentin after application of either polyacrylic acid or self-etch adhesive bonding systems. They reported that pretreatment of dentin with self-etch adhesive systems, before placing a RMGI, seems to be a good alternative to the conventional dentine conditioner. Khoroushi et al[58] compared the effect of a conditioner, an etch-and-rinse, and a self-etch adhesives and in comparison to similar composite resin restorations on maintaining the marginal sealing of RMGI restorations. The results of the study showed that the use of two-step self-etch adhesive systems instead of a conventional cavity conditioner improves the marginal integrity of RMGI restorations at both enamel and dentin margins.

The application of dentin-bonding systems has been reported to increase the bond strength between composite and RMGI.[73,74] Arora et al[74] evaluated and compared the ability of adhesive agents to bond the composite resin to RMGIs. The study reported that application of self-etch adhesive (Adper prompt-L pop) in between RMGI and composite resin increases the shear bond strength between RMGI and the resin composites, as compared to the etch and rinse adhesives (Adper Single Bond 2), as well as, without application of the adhesive agent. Similarly, Kasraie et al[73] reported that the application of self-etch adhesives resulted in a greater increase in micro-shear bond strength between RMGI and resin composite compared with the use of etch and rinse systems. Moreover, Sadeghi et al[75] investigated the shear bond strength of resin composite bonded to RMGI utilizing different adhesive agents and a GIC-based adhesive (Fuji Bond LC). Their study recommended the application of self-etch over etch and rinse adhesives. Barcellos et al[76] reported that acid etching before applying an etch and rinse (Adper Single Bond 2) or self-etching adhesive (Clearfil SE

Bond) increased the bond strength of RMGI to the composite resin.

RMGI bases should be applied in 1 mm layers if indicated.[27] Restorations with a layer of 1 mm RMGI base beneath a resin composite restoration has been reported to reduce dye staining and micro-gap formation in comparison to that with the thinner (0.5 mm) lining.[27] In general, it is preferable to have a 2 mm thickness of bulk between the pulp and a metallic restorative material. This bulk may include remaining dentin, liner, or base. Composite resin materials do not require the same thickness between the restoration and the pulp. A base should never compromise the recommended thickness of the amalgam or composite.

Conclusion

This review emphasizes that the available literature provides very little evidence to support the routine use of a base under amalgam or composite restorations. This review favors the adoption of 'no more lining or bases' in shallow and moderate cavity preparations. However, an exception might be a "protective base" of RMGI following the application of CH liners in deep cavities. Bases can also be used to block out undercuts or for internal buildups for indirect restorations. Bonded RMGIs are suitable cavity base materials and should always replace zinc oxide eugenol bases in daily practice.

Disclosure

The authors report no conflicts of interest in this work.

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