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REVIEW

Calcium hydroxide liners: a literature review

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Objective: This review integrates the literature on cavity liners and current concepts of pulp protection with the aim of establishing a better understanding of the role of calcium hydroxide as a cavity liner.

Materials and methods: A search was conducted through PubMed, MEDLINE, and Ovid for articles with the criteria for the following terms: cavity liners and bases, pulp protection, and calcium hydroxide liners. No specific inclusion or exclusion criteria were applied as to what articles would be included in this review. It was hoped that the extent of the literature reviewed would be as comprehensive as possible.

Conclusion: This review underlines the fact that calcium hydroxide liners should only be used in the deepest spots in the cavity where the remaining dentine thickness is ≤0.5 mm. A protective layer of resin-modified glass ionomer should always follow the application of calcium hydroxide liners.

Keywords: liners, calcium hydroxide, pulp protection, pulp therapy, bases

Introduction

One of the aims of operative dentistry is to preserve the pulp vitality in compromised teeth: one method used for this reason is the use of liners and bases. This involves the placement of protective materials on the unexposed pulp to maintain its health and to stimulate defensive repair by tertiary dentine deposition. The use of liners and bases under restorations has been common practice for many years and continues to be promoted in operative dentistry textbooks as an essential part of restorative procedures.[1–3] The concepts related to pulp protection have been constantly revisited as the knowledge and understanding of the tooth and dental materials evolve.[4–8] Traditionally, liners have been used to protect the pulp from the potential toxic effects of restorative materials. Currently, liners are used for their therapeutic effect and/or to seal the dentinal tubules against the ingress of microorganisms or their by-products at the restoration–tooth interface.[4,9] A variety of dental materials have been introduced as liners to provide pulp tissue protection from irritants related to the restorative procedure. The traditional lining materials include calcium hydroxide, glass ionomer, and resin-modified glass ionomers (RMGIs). Calcium hydroxide has been considered as gold standard for a long time and enjoys the greatest popularity among general dentists. In clinical practice, calcium hydroxide has been reported as liner of choice in patients with deep cavities.[10–12] This review aims to integrate the literature on calcium hydroxide liners to provide the general dentist with a comprehensive overview that facilitates a better

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understanding of the material and its clinical application in operative dentistry.

Review

The definition of a "liner"

The definition of liners itself has been a source of confusion in dental literature. Marzouk et al[13] defined cavity liners as film-forming materials that carry therapeutic agents, which create their greater film thickness (up to 25 μm) and usually applied to dentine only. Ferracane[14] described a liner as material that is applied in a thin layer to seal the dentine on the floor and walls of the cavity against the influx of bacteria or irritants from restorative procedures. In 1994, *The Journal of Operative Dentistry* published a letter submitted by Summit[15] in which he enlisted cavity liners, varnishes, and resin-bonding agents as subcategories of cavity sealers. He proposed a definition of a cavity liner as a cement or resin coating with minimal thickness (usually <0.5 mm) to achieve a physical barrier to bacteria or a therapeutic effect (a chemical effect which in some way benefits the health of the pulp of the tooth). Later on, McCoy[16] submitted a letter to *The Journal of Operative Dentistry* in which he made changes to the original definitions and structure (based on the feedback from *Operative Dentistry* readers) previously made by Summitt.[15] McCoy stated that pulp protection materials should be classified into categories based on an increase in thickness and viscosity. Hence, liners were categorized in a separate category and maintained the same definition previously proposed by Summitt. Hilton[6] defined cavity liners as materials placed with minimal thickness (usually <0.5 mm), which act as cavity sealers and provide expanded beneficial functions, such as fluoride release, adhesion to tooth structure, and/or antibacterial action that promotes the health of the pulp. Ten years later, Hilton[17] defined cavity liner as cement or resin coating of minimal thickness (≤0.5 mm) that acts as a barrier to bacteria, as well as typically providing a therapeutic effect, such as an antibacterial or pulpal anodyne effect. They added that the placement of the liner is often, but not always, limited to the dentine closest to the pulp. Qualtrough et al[1] defined a cavity liner as an aqueous or volatile organic suspension or dispersion of zinc oxide or calcium hydroxide that can be applied to a cavity surface in a relatively thin film. They included glass ionomer and RMGI cements as materials suitable for use as lining materials. Weiner[18] defined a cavity liner as a thin layer of material (0.5 mm) placed on the surface of the tooth preparation that, in part, protects the tooth from the restorative material, intraoral fluids, and ultimately from the outside environment but usually do not have sufficient thickness, hardness, or strength to be used alone in a deep cavity. Similarly, Heymann et al[3] defined liners as suspensions or dispersions of zinc oxide, calcium hydroxide, or RMGI that can be applied to a tooth surface in a relatively thin film. Anusavice et al[19] stated that a cavity liner is a material that is used to coat the bottom of a prepared cavity to protect the pulp; it is applied in a thin layer and usually contains calcium hydroxide or mineral trioxide aggregate (MTA); it also includes certain glass ionomer cements used as intermediate layers between tooth structure and composite restorative material.

It is important to distinguish between two terms "liners" and "suspension liners". Both terms should not be used synonymously. Liners (previously referred to as low-strength bases or cement liners or subbases) are materials placed in deep portions of the cavity preparations that harden when mixed to form a cement layer (100–500 μm) usually with minimum strength and low rigidity functioning as a barrier to irritating chemicals and providing therapeutic benefit to the pulp. Suspension liners are set by physical means (drying) and upon the evaporation of the volatile solvent form a relatively thin film (20–25 μm) that serves as a protective barrier between dentine and the restorative material and provides some therapeutic effect and provide no mechanical strength, no thermal insulation, and should only be used to line dentine.

Types

In situations where a liner is indicated, there are several choices of materials. These include calcium hydroxide, RMGI, MTA, and zinc oxide eugenol (ZOE). ZOE liners[20] (ISO 3107:2004 Type IV) are highly ranked for their antibacterial potential.[21] ZOE liners are rarely used or marketed as a cavity liner nowadays;[22] the updated version of the ISO standards on ZOE and zinc oxide/noneugenol cements (ISO 3107:2011) does not categorize ZOE as a liner. These liners are relatively weak in thin layers, soluble, do not stimulate reparative dentine, and demonstrate high interfacial leakage, for example, Cavitec (Kerr Portland, OR, USA). MTA was also listed by some textbooks as a cavity liner.[19] However, despite its excellent antibacterial effect,[21,23] MTA is not recommended as a cavity liner due to its low compressive strength and very slow setting times, which makes it difficult in handling and technique sensitive, especially beneath definitive restorations.[24] RMGI liners are formulated from fluoroaluminosilicate glasses, photoinitiators, polyacrylic acid, water, and a water-soluble methacrylate monomer, such as hydroxyethyl methacrylate, which may or may not be integrated onto the polyacrylic acid.[25] They were developed in an attempt to improve mechanical properties, decrease setting time, and attenuate moisture sensitivity of conventional glass ionomers. RMGI liners provide adequate sealing and protection to the dental pulp due, in part, to the chemical adhesion to dental substrates combined with their ability to release fluoride,[22] for example, Vitrebond (3M, ESPE) and GC Fuji II LC (GC Corporation, Tokyo, Japan). Of all these materials, calcium hydroxide was initially proposed by Hermann[59] in 1930 as a "remineralizing agent" in direct pulp capping, and calcium liners probably enjoy the greatest popularity among general dentists and have been considered to be the gold standard by which other vital pulp modalities are measured.[9]

There are a variety of views and approaches when it comes to using cavity liners.[11,26–28] A 1995 survey on teaching the use of bases and liners concluded that dental schools in North America do not agree on which liner material to use and when to use it. In the mid-1990s, for a deep cavity that was to be restored with an amalgam, 46% of the 52 schools that replied advocated the use of a glass ionomer as a liner followed by 25% in favor of calcium hydroxide. The survey considered cavities with 1 mm remaining dentine thickness (RDT) as deep cavities since there were no strict guidelines for defining a deep cavity in the literature at that time.[26] Likewise, in a more recent survey on liners taught by dental schools in North America, there was no agreement on a standard pulp protection protocol. Thirty-eight percent of the 39 dental schools involved in the survey reported that calcium hydroxide liners were taught for deep preparations with amalgam restoration followed by 30.8% that taught glass ionomer liners. The survey also reported that for composite restorations in a deep cavities, the liners most frequently used were glass ionomers (35.9%) followed by calcium hydroxide (28.2%). However, the 1995 survey did not offer scenarios that included composite restorations.[27] Another study investigated the practice of dental pulp protection methods among 500 final year students, young clinicians, and interns in various teaching institutions in Pakistan and concluded that the contemporary protocols for pulp protections are not being followed by the respondents in the institutions that participated in the survey, for example, ~89% of the respondents did not consider RDT essential while 82% of them considered using calcium hydroxide liners essential under all direct restorations.[28]

Conventional calcium hydroxide liners

Calcium hydroxide for the purpose of pulp protection is available in various forms, such as in aqueous suspensions or as cements, liners, or filled risens. Calcium hydroxide aqueous suspensions are suspensions of calcium hydroxide in water. After application, the solvent evaporates, leaving behind (as a liner) a layer of calcium hydroxide, for example, Pulpdent (Pulpdent, Brookline, MA, USA). Calcium hydroxide liners, however, are a combination of calcium hydroxide with a varnish to modify the viscosity and to improve handling,[20,29,30] for example, Hydroxline (George Taub, Jersey City, NJ, USA). Calcium hydroxide cements are paste/paste systems. One paste contains calcium hydroxide and the other contains salicylate. Salicylate is a weak acid that is chemically similar to eugenol and reacts with the calcium hydroxide.[29] The acid–base reaction between calcium hydroxide and a salicylate is responsible for setting, the reaction forms an amorphous calcium disalicylate.[31] This form of calcium hydroxide materials fit into what was previously described as low-strength bases,[32] for example, Dycal (Dentsply, Milford, DE, USA) and Life (Kerr, Portland, OR, USA).

Ideally, liners should possess antibacterial properties. The ability of these liners to prevent bacterial growth under restorations is of great importance as the numbers of bacteria in a cavity decrease the extent of pulpal inflammation is reduced. Calcium hydroxide liners are reported to display antibacterial properties.[33] The antimicrobial properties of calcium hydroxide come from its dissociation into calcium and hydroxyl ions. The hydroxyl ions create an alkaline pH that is unfavorable for remaining bacteria in the cavity. Hydroxyl ions are highly oxidant free radicals that show high reactivity.[34] The antimicrobial action of hydroxyl ions on microorganisms can be explained by their influence on growth, structure, metabolism, and bacterial cell division.[23,30] The antibacterial properties of calcium hydroxide were reported inferior to RMGI liners[35,36] and stronger than other materials commonly used for lining (especially the conventional glass ionomer cement). Calcium hydroxide liners were also reported to reduce bacterial numbers much more effectively than only sealing the cavity.[21] However, calcium hydroxide liners show reduced antibacterial activity overtime.[37]

Calcium hydroxide has significant drawbacks; the low elastic modulus and low compressive strength of calcium hydroxide cavity liners restricts their usage to thin layers in specific areas, which is not critical to the support of restorations.[31,38] Calcium hydroxide liners have low thermal conductivity, but they are usually not used in thick enough layers (≤0.5 mm) to provide thermal protection;[20] therefore, thermal protection should be provided with a separate base. Hence, it is recommended that they should be only applied over the smallest area that would suffice to aid in pulp therapy.[2] Calcium hydroxide liners must not be left on the margin of the prepared cavity or the margin will not be properly sealed because the liner is soluble in water.[19] It has high solubility and water sorption,[39] which may result in softening of the liner and in material loss under poorly sealed tooth–restoration interface where the oral fluids can penetrate through and partially or totally dissolve this pulp-protecting material.[9] This was previously described in the literature as the "Disappearing Dycal" syndrome.[7] Calcium hydroxide liners should not be acid etched as it might be softened and smeared over the walls of the cavity, which may contaminate acid-etched enamel and produce an inferior bond.[40,41] Phillips et al[40] reported that the solubility of calcium hydroxide (paste/paste) liners in phosphoric acid (37%) varies markedly among brands and it is dependent on the commercial preparation. The same study also reported that solubility of calcium hydroxide might be sensitive increase in base/catalyst ratio.

Operative dentistry books recommend a calcium hydroxide liner if the excavation extends close to the pulpal tissue.[3] Current concepts on pulp protection define "close to the pulp" as the case where the RDT between the floor of the cavity preparation and the pulp is ≤0.5 mm.[42] Calcium hydroxide liners are reported to mediate underlying odontoblasts survival when the RDT is ≤0.5 mm.[42,43] Maintaining the health and vitality of the odontoblast cell layer is important as it is responsible for the capacity of the dental pulp to protect itself by the deposition of tertiary dentine secreted by primary odontoblasts.[44] The influx of calcium ions from the dissociated material toward the pulp triggers the recruitment and proliferation of undifferentiated cells from the pulp and activates stem cells.[45] Calcium hydroxide has the ability to slightly demineralize dentine, and in turn release transforming growth factor-β1 from the matrix that signals tertiary dentinogenesis that is responsible for repair in dentine pulp complex and, in turn, supports the success of much of restorative dentistry.[46–48] About et al[49] reported that calcium hydroxide maintained the highest number of odontoblasts (compared to zinc polycarboxylate, ZOE, and RMGI) beneath restored cavities when the RDT is <0.5 mm. Murray et al[42,50] reported that in cases with a cavity RDT is <0.5 mm and no pulp exposure is present; calcium hydroxide liners displayed the greatest area of reactionary dentine deposition when compared with other pulp-protecting materials, such as RMGI, ZOE, and zinc polycarboxylate. In cases where the RDT is between 0.5 and 1.5 mm, calcium hydroxide liners are not necessary.[4] Instead, an RMGI liner should be used to replace the lost dentine and to provide volumetric reduction of composite resins to reduce the drawbacks of polymerization shrinkage of dental composites. RMGI provides adequate sealing and protection to the dental pulp due, in part, to the chemical adhesion to dental substrates, fluoride release, decreased solubility, and superior mechanical properties.[4,31] However, they should not be used in deep cavities where the RDT is ≤0.5 mm in order to limit pulp injury.[42]

The current protocols for pulp protection impose a protective RMGI base wherever calcium hydroxide liners are indicated to compensate for the drawbacks of calcium hydroxide 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. Calcium hydroxide liners do not adhere to dentine or resin-based restorative materials. Hence, they provide a poor seal. The adaptation between dentine and Dycal and also between Dycal and Vitrebond (3M ESPE) was evaluated under scanning electron microscope (SEM), marked gaps were seen between Dycal and dentine, on one hand, and between Dycal and Vitrebond, on the other hand. The study attributed the gaps to the lack of adhesion of Dycal to Vitrabond and dentine as well.[51] Similar results were also reported by another SEM study by Chen et al,[52] which concluded that there was a big gap between Dycal and the overlying Vitrebond. Therefore, enough enamel and dentine should be left exposed for adhesion of the overlying protective RMGI layer since studies report good adaptation and bonding between dentine and Vitrebond.[4,51,52]

Due to their alkaline nature, they also serve as a protective barrier against irritants from other restorative materials; using calcium hydroxide liners under RMGI is the best way of avoiding needles odontoblast injury that might result from applying RMGI in deep cavities.[53] Calcium hydroxide liners are also recommended as a protective layer "subbase" beneath a ZOE temporary restoration.[54] Similarly, in deep cavities with minimal remaining dentine covering the pulp, calcium hydroxide liners are recommended as a protective layer under zinc phosphate cements – to help reduce the effects of the initial low pH (4.2 at 3 minutes).[55]

Light-cured calcium hydroxide liners

A single component liner that contains calcium hydroxide and is polymerized by visible light was introduced in 1988 to help address the limitations of the chemical cure calcium hydroxide; that is, they set on command, improved strength, essentially no solubility in acid, and minimal solubility in water.[56] A visible light-cured (VLC) calcium hydroxide liner consists of calcium hydroxide and barium sulfate dispersed in a urethane dimethacrylate resin containing initiators and accelerators activated by visible light.[31] The fact that this material is based on polymeric resins allows for bonding between it and the overlaying composite restoration.[39,56] It should be noted that if subsequent use of a dentine-bonding agent is desired, the VLC liner should only be applied on the deepest (<1 mm remaining) dentine, leaving the rest of the cavity surface free for bonding. VLC calcium hydroxide liners are mainly indicated for indirect pulp capping and as a cavity liner under all types of restoratives, for example, Calcimol (Voco GmbH, Cuxhaven, Germany) and Lime-lite (Pulpdent Corporation, Watertown, MA, USA).

There is little proof that VLC calcium hydroxide liners actually release calcium ions necessary for reactionary dentine formation. A study by Gandolfi et al[45] compared the release of calcium ions by Dycal, Life, and Lime-Lite and found that the amount of calcium released by Lime-Lite was negligible compared to that released by the chemical set formulas (Dycal and Life). There is little proof of considerable antibacterial effect of the VLC calcium hydroxide liners; the vehicle component of these light-cured products may prevent or significantly reduce any antimicrobial effects associated with the chemical cure products. McComb and Ericson[33] reported significant difference in the antibacterial effect between a conventional two-paste calcium hydroxide cement (Advanced Formula II Dycal, LD Caulk Co/ Dentsply) and the visible-light-cured liner containing calcium hydroxide (Prisma VLC Dycal, LD Caulk Co/ Dentsply). They reported no antibacterial activity of the light-cured calcium hydroxide liner (Prisma VLC Dycal) and concluded that this material was inert. Coogan and Creaven[37] reported that the antibacterial action of Prisma VLC Dycal is limited and its antibacterial properties were significantly less than that displayed by the chemically cured Dycal. Similarly, Poggio et al[23] studied the antimicrobial effect of Calcimol LC and Dycal using an agar diffusion test and found Dycal to have a significantly higher antimicrobial activity compared to the Calcimol LC. Staehle et al[30] studied the alkalizing properties of calcium hydroxide compounds and reported that the degree of ion release, combined with definite antimicrobial properties for light-cured calcium hydroxide is lower than that of the conventional paste/paste forms of calcium hydroxide. However, Lado and Stanley[57] compared the antimicrobial activity of light-cured calcium hydroxide pulp capping products to self-cure products by an in vitro microbial assay and reported that all the products tested resulted in similar size zones of inhibition ($P<0.10$). They concluded that the VLC products are equally effective as standard self-curing, pulp capping products in inhibiting the growth of organisms commonly found at the base of a cavity preparation. Yalcin et al[58] investigated the antibacterial effects of Dycal and the light-cured calcium hydroxide liner (Calcimol LC) using the direct contact test. The authors reported that both of these materials showed no antibacterial activity.

Conclusion

Calcium hydroxide liners should not be overused. Calcium hydroxide liners are used for its bioinductive and antimicrobial activity. It should be only used in the deepest spots in the cavity where the RDT is ≤0.5 mm. The placement of calcium hydroxide should be followed by a layer of RMGI to protect it from its drawbacks.

Disclosure

The author reports no conflicts of interest in this work.

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