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Review Article

Secondary caries formation in aged restorations: a clinical review

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ABSTRACT

Secondary caries, or recurrent caries, occur at the margins of existing restorations and are influenced by multiple factors, including the characteristics of the restoration material. The pathogenesis of secondary caries mirrors that of primary caries, involving enamel demineralization and the dissolution of organic components, but is modified by the presence of restoration margins. Defective restorations create gaps that allow acidic fluids and biofilms to intrude, while intact restorations can also be susceptible due to the lower buffering capacities of restorative materials compared to natural tooth structure. The incidence of secondary caries differs between restorative materials, with composites exhibiting a higher susceptibility (ranging from 0% to 44%) compared to amalgams. Contributing factors include polymerization shrinkage, microleakage, increased plaque retention, and the lack of antibacterial properties in composites. Diagnosis typically involves visual inspection and radiographic analysis, with indicators such as marginal ditching, staining, and gaps serving as potential predictors. However, reliance on these indicators can lead to misdiagnosis and unnecessary restorative replacements; studies show that 50% to 60% of restorations are replaced due to secondary caries, often overestimated as actual replacement rates range from 2% to 3%. Notably, resin composites display greater sensitivity to application techniques and plaque accumulation, leading to secondary caries. Clinical proficiency in both amalgam and composite restorations can enhance restoration longevity. Key factors influencing the failure rates of restorations include patient age, history of extensive caries, cavity depth, and preparation technique. This review emphasizes understanding secondary caries' impact on restoration longevity and advocates for tailored clinical management in caries treatment and restoration placement. The interaction between caries-related bacteria and the restorative interface further complicates the pathophysiology of secondary caries, underscoring the need for careful assessment and management strategies.

Keywords: Secondary caries, Failed restorations, Composite restoration, Recurrent caries, Microleakage

INTRODUCTION

Secondary caries are carious lesions that occur at the margins of an existing restoration or cement. Secondary caries is also defined as recurrent caries.[1,2] It is a multifactorial process; in addition to the known causes of primary caries, the characteristics of the restoration and restorative material play a crucial role in the development of secondary caries.[3] The pathogenesis of secondary caries is similar to the pathogenesis of primary caries, including enamel demineralization and enzymatic dissolution of the organic component; however, the presence of a restoration or sealant margin modifies the pathogenesis.[3]

Secondary caries frequently arises in conjunction with defective restorations, as the gaps between the restorative material and the tooth create avenues for the intrusion of acidic fluids and biofilm at the interface. Additionally, recurrent caries can occur even in the presence of intact restorations, attributed to the reduced buffering capacity of the restorative material when compared to natural tooth hard tissue. In certain instances, if primary caries exists adjacent to a restoration, the margins of the restoration may also become susceptible to carious lesions.[3-5] Secondary caries has a higher incidence with composites than with amalgams, ranging between 0% and 44%.[6] Composites are more susceptible to secondary caries due to the presence of

polymerization shrinkage and subsequent micro leakage, the release of bacteria-stimulating compounds, higher plaque accumulation, changes in microbial composition, and the lack of antibacterial and acid-buffering effect. The incidence of secondary caries is often associated with the longevity of restorations.[7]

Secondary caries can be evaluated through both visual inspection and radiographic analysis. Clinical indicators such as marginal ditching, staining and discoloration of the restoration and surrounding dental tissues, as well as the presence of gaps at the interface of the tooth and restoration, serve as potential predictors for secondary caries.[8] However, it is important to note that these indicators are not wholly reliable for definitive diagnosis. For instance, a stained line surrounding a restoration may be misinterpreted as microleakage, while arrested caries can manifest as a gray discoloration in the restoration.[8] Furthermore, radiographic assessments can yield both overestimations and underestimations of lesion extension, complicating clinical interpretation. Factors such as the radiopacity of restorative materials, the presence of bonding layers, and the existence of residual caries can also contribute to the misinterpretation of radiographic findings. Consequently, while these diagnostic methods provide valuable insights, they should be used with caution and in conjunction with other clinical evaluations to ensure accurate assessment of secondary caries.[8]

Such confusion can result in the undue replacement of restorations, which results in further damage to tooth structure. Approximately 50% to 60% of the restorations are replaced due to secondary caries, which is significantly overestimated since the percentage of restorations replaced in several studies often ranges between 2% to 3%.[8] Resin composite materials exhibit a higher sensitivity to technique compared to dental amalgam; however, they are also more prone to plaque accumulation, which can lead to the development of secondary caries.[9] It was found that practitioners who possess proficiency in the application of both amalgam and resin composite restorations can enhance the longevity of these dental restorations. Specifically, secondary cars are identified as the predominant reason for the replacement of resin-composite restorations. Furthermore, the failure rate of these restorations is significantly correlated with several factors, including the young age of the patient, a history of extensive caries, the depth of the cavity, and the utilization of the saucer-shaped preparation technique.[9] These insights underline the importance of tailored clinical approaches in the management of dental caries and restoration placement to maintain the longevity of the restorations placed. This review article aims to highlight the formation of secondary caries in restored teeth and its impact on the longevity of the restorations.

METHODS

This narrative review is based on a comprehensive literature search conducted on 07 August 2025, using ScienceDirect, PubMed, Wiley Library, Dynamed, MDPI, Oxford Academic, BMC, and Cochrane databases. The research utilized Medical Subject Headings (MeSH) terms and relevant keywords, such as secondary caries and their effect on present restorations, to identify studies that examined secondary caries and impact on the integrity of the tooth structure and the longevity of the restoration. A manual search was also conducted using Google Scholar, and the reference lists of identified papers were reviewed to locate additional relevant studies. No restrictions were applied regarding publication date, language, participant age, or type of publication, ensuring a broad and inclusive exploration of the available literature.

DISCUSSION

Caries lesions are caused due to the imbalance between pathological factors that cause loss of minerals and protective factors that uptake ions.[10] Certain bacterial species produce organic acids that demineralize the organic and inorganic structure of the tooth.[10] Although the pathophysiology of secondary caries is similar to that of primary caries, it is more complicated due to the presence of a restoration that interacts with the biofilm present on the surface and the interface. For instance, secondary caries comprises a higher proportion of cariogenic bacteria than that found in primary caries.[11] This significant difference in the number of cariogenic bacteria is attributed to the presence of a resin-based restorative material.[12] Additionally, the bacterial composition found under the restorations is similar to that found in the plaque biofilm, including *Streptococcus* and *Actinomyces spp.*[13] *S. mutans* bacteria are a significant marker of secondary caries regardless of the causative microorganism.[14]

Defective resin-based composite restorations stimulate the growth of cariogenic threatening the vitality of the pulp. These changes observed in restorations, especially resin-based restorations, are attributed to the microspace between the restoration and the cavity floor, which is susceptible to harboring anaerobic bacteria (Figures 1 and 2). Such bacteria are associated with symptoms, such as pulpitis or pain.[11] The type of restorative material is crucial in the formation of biofilm on the surfaces and interfaces of dental restorations and surrounding tooth tissues. Lesions of secondary caries have two distinct regions, which are the surface lesion and the wall lesion.[11] Surface lesions develop perpendicular to the tooth surface and adjacent to a restoration, whereas wall lesions develop in-depth and perpendicular to the tooth/restoration interface. Wall lesions result from microleakage and are often found in teeth with occlusal amalgam restorations.[11] Additionally, failed bonded interfaces in resin-based restorations and non-bonded interfaces result in wall lesions as well.[15]

There are multiple factors affecting the development of secondary caries lesions, which include the restoration type, size, and location; material properties; persistent interfacial gaps and microleakage; high technique

sensitivity of the restoration; polymerization shrinkage; biodegradation; and mechanical degradation, in addition to the patient-related risk factors.[15] The presence of interfacial gaps and microleakage at the tooth/restoration interface is considered the main reason for secondary caries formation, leading to the leakage of bacteria and their metabolites, contributing to the development of secondary caries, regardless of the type of restorative material.[16] This theory has been confirmed by Kuper et al in an in situ study, in which they found that the presence of a gap renders composite restorations susceptible to secondary caries, particularly in high caries risk patients.[17] Further evidence has shown that a gap of only 70 µm can lead to microleakage and demineralization of the tooth/restoration interface and form wall lesions.[17] However, Barata et al in their in situ study, argued that secondary caries are primary caries that develop at the margins of the restorations.[18] Despite different theories that exist regarding the impact of microleakage on the development of secondary caries, it is still a significant factor influencing the integrity of the tooth-restoration interface. Gaps can arise during the placement of composite restorations, as this material is technique-sensitive, particularly in patients at high risk for caries.[15]

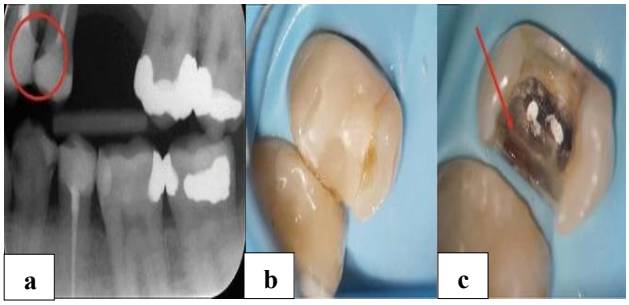

Figure 1 (a-c): Secondary caries at the margin of a defective composite restoration.[15]

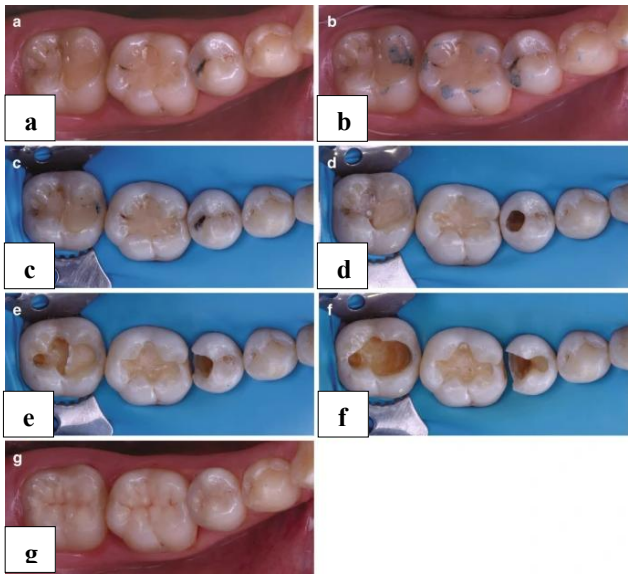

Figure 2 (a-g): Replacement of a defective composite restoration due to the presence of secondary caries.[11]

Microleakage in composite restorations is predominantly attributed to the sensitivity of the techniques employed during their application. Several factors contribute to this phenomenon, including inadequate etching of enamel, excessive etching of both enamel and dentin, insufficient application or curing of the bonding agent, and poor wetting of dentin following etching. These shortcomings may result in microleakage or nano-leakage at the restoration interface.[19] To avoid secondary caries in composite restorations, using simplified adhesion protocols reduces the application errors.[20] Furthermore, the adaptation of composite materials within the cavity can lead to the formation of voids and porosities. Notably, when these defects exceed 1 mm, particularly at the margins of the restoration, they can significantly compromise the integrity of the seal, thereby facilitating microleakage.[21] Polymerization shrinkage is another drawback of composite restorations that results in the development of secondary caries. Polymerization shrinkage in composite restorations ranges between 1.5% and 5%.[22] Hence, results in stress-relieving gaps at the tooth-restoration interface.[15] Therefore, to reduce the development of secondary caries caused by gaps from polymerization shrinkage, the composite material should be placed in increments.[23] In addition to the factors related to the restoration and the clinician's skills, there are factors related to the patient.[24] Behavioral and dietary habits directly affect the longevity of the restoration. The biofilm accumulation, temperature fluctuations, increased snacking frequency, and decreased toothbrushing frequency create several challenges to the survival of the restoration. Such fluctuations lead to hydrolysis, fatigue, leaching, and cracking of the restoration.[25] The frequent exposure to carbohydrates, which leads to an increased acidification of the plaque and tooth demineralization, undermines the integrity of the restoration, especially composite restorations.[26] Therefore, improving the patients' behavior can prevent the development of secondary caries and restoration failure.

The composition of saliva is fundamental to the pathogenesis of both primary and secondary caries within the oral cavity. Salivary proteins, including mucins, cystatins, and proline-rich proteins, play a pivotal role in modulating the oral biofilm's architecture. These proteins facilitate the process of remineralization, inhibit demineralization, attenuate microbial adherence, neutralize acidic environments, and safeguard tooth structure against fluctuations in salivary pH.[27] Furthermore, the presence of salivary proteins has been shown to significantly reduce bacterial counts, a phenomenon that is particularly evident following the sealing of dental cavities. This complex interplay underscores the importance of saliva in maintaining oral health and preventing cariogenic processes. The texture of saliva has a significant role in the development of caries, either primary or secondary. Saliva with increased viscosity and thickness often renders teeth susceptible to more microorganism adherence to the tooth or restoration, hence results in demineralization of the tooth structure and

development of caries.[25] For instance, patients suffering from xerostomia, which is a disease affecting the quality and quantity of saliva, are often more prone to experience restoration failure, especially large composite restorations.[28] Xerostomia, or dry mouth, is a medical condition characterized by reduced salivary flow, and it can be attributed to a variety of underlying diseases and treatments. Conditions such as human immunodeficiency virus (HIV), hepatitis C virus (HCV), uncontrolled diabetes, Alzheimer's disease, Sjögren's syndrome, hypertension, burning mouth syndrome, and certain malignancies have been identified as significant contributors to xerostomia. Patients suffering from these conditions often exhibit a high caries index and require numerous dental restorations.[29] Moreover, xerostomia can also result from cancer treatments such as chemotherapy and radiotherapy, as well as the use of over 500 different medications.[30] The carious lesions associated with these treatments are primarily due to a substantial decrease in salivary gland output and an increase in saliva viscosity. This reduction in saliva not only enhances the risk of dental caries but also compromises the longevity and success of dental restorations.[25]

The caries index of an individual is a critical determinant in assessing the longevity of dental restorations and the associated caries risk. Employing caries risk assessment techniques facilitates the formulation of an optimal treatment plan and the selection of the most appropriate restorative materials.[25] Research indicates that patients categorized as having medium to high caries risk are two to three times more likely to experience restoration failure and develop secondary caries. Furthermore, individuals presenting with a high decayed, missing, and filled teeth (DMFT) index demonstrate an approximately fourfold increased likelihood of encountering secondary caries and subsequent restoration failures.[25] The presence of gaps or the absence of adjacent teeth further exacerbates the risk for secondary caries and restoration failure by creating conditions conducive to plaque accumulation. Moreover, periodontal diseases significantly influence the durability of restorations and contribute to the incidence of secondary caries. Conditions such as deep periodontal pockets, gingivitis, and periodontitis lead to an elevation in bacterial counts, which may serve as a reservoir for pathogenic bacteria within periodontal tissues.[25] This bacterial proliferation complicates carious lesions and can result in the reinfection of previously restored teeth, thereby fostering the development of secondary caries and undermining the longevity of dental restorations.

There is a significant correlation between age and the development of secondary caries and the failure rates of restorations, particularly resin composite restorations. For instance, adolescents exhibit heightened failure rates due to their increased consumption of sugary snacks and soft beverages, and a lack of adequate oral hygiene practices, which eventually result in secondary caries.[25] However, older adults, especially those aged 65 and above, display increased susceptibility to restoration failures due to several factors inherent to their demographic, which include the presence of older dental restorations, a higher incidence of dental caries, and various physiological changes within their stomatognathic system as they age. Such changes include impaired motor functions, diminished salivary flow, general health issues, greater reliance on medications, and an overall decline in the ability to maintain proper oral hygiene.[25]

The socioeconomic status is a pivotal factor that influences the longevity of composite restorations and the development of secondary caries. Socioeconomic deprivation significantly correlates with higher rates of secondary caries and restoration failure. This is attributed to cultural, sociological, educational, and psychological factors that contribute to disparities in oral care practices, subsequently resulting in secondary caries and the durability of dental restorations.[25] Individuals from lower socioeconomic backgrounds frequently experience a higher frequency of restorative failures in comparison to their more affluent counterparts. For instance, restorative efforts conducted in dental clinics located within deprived areas demonstrate annual failure rates of approximately 5.6%, contrasted with 4.2% in medium socioeconomic contexts and 5.1% in high socioeconomic areas.[25] Additionally, multiple socioeconomic factors, such as poor adherence to oral health guidance, lower levels of maternal education during childbirth, and irregular dental visits, are significantly associated with the development of recurrent caries and restoration failures.[25]

CONCLUSION

Secondary caries often develops in failed restorations due to a variety of factors, which can be patient-related, clinician-related, or material-related. Regardless of the specific causes, it is important to recognize that secondary caries not only incurs additional costs but also consumes valuable time for both patients and clinicians. Moreover, it compromises the integrity of the tooth structure, leading to further damage. Given the multifactorial nature of this issue, a comprehensive approach is necessary for resolution. Patients should prioritize maintaining good oral hygiene and scheduling regular dental checkups, while clinicians must adhere to strict protocols when placing restorations, especially those that are technique-sensitive. This review article addresses a gap in the literature concerning the development of secondary caries in aging restorations and emphasizes the need for further research on this topic.

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