



RISK FACTORS FOR THE DEVELOPMENT OF SECONDARY CARIOUS LESIONS (SCLS) IN PRIMARY DENTITION- A REVIEW

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ABSTRACT

Secondary carious lesions (SCLs) are the main cause for failure of restorations and pose challenges in primary dentition due to the anatomical and physiological characteristics of the primary teeth. The objective of this article is to synthesize the information about the risk factors involved in the formation of SCLs in primary teeth. Material-related risk factors include the increased biofilm formation on composites, surface and chemical properties, residual monomer release, polymerization shrinkage, and biodegradation. The risk factors related to the patients are overall caries risk, oral-hygiene behaviors, diet, existing caries burden, and socioeconomic status. Operator-related factors are the moisture control, strict adherence to adhesive protocols, and quality of finishing. Cavity-related risks are highest for Class II restorations, particularly at gingival margins and proximal cervical areas of primary molars. The diagnosis is challenging because visual-tactile methods underdetect early and approximal lesions, bitewing radiography remains imperfect, and newer, modern technologies are promising yet not routine. Prevention must therefore be multifactorial, combining individualized risk assessment, optimal material selection, meticulous technique, biofilm management, and tailored recall. Continued pediatric-focused prospective research is needed to refine evidence-based strategies.

Keywords: secondary caries lesions (SCLs), primary dentition, pediatric dentistry, composite restorations, risk factors, , fluoride release, diagnosis, prevention,

BACKGROUND

A secondary carious lesion (SCL) is defined as a primary carious lesion that develops in contact with an existing restoration (at the tooth–restorative material interface) after the restoration has been in service for a certain period of time [1]. It is the most common complication following operative treatment and the leading reason (between 50–70%) for replacement of restorations, regardless of their type [1, 2]. These lesions shorten restoration longevity, lead to additional loss of tooth structure, and necessitate further financial costs and treatment time [2].

The problem of SCLs is particularly significant in the primary dentition. There are anatomical and physiological differences between primary and permanent teeth that determine a different course of carious lesions in the two dentitions [3]. The enamel of primary teeth is thinner than that of permanent teeth and has a uniform thickness over the cusp and cervical areas [3, 4]. These features, together with the lower mineral content, make the enamel of primary teeth more permeable and more susceptible to the development and progression of carious lesions than the enamel of permanent teeth [3, 4]. The dentin of primary teeth is also thinner and less mineralized [4]. These characteristics render primary teeth more prone to caries development and to progression toward complicated lesions [4].

The specific characteristics of primary teeth have important implications for the design and dimensions of cavity preparation, as well as for the choice of restorative material. The small size of the crown in primary teeth results in the involvement of a relatively larger proportion of the coronal hard tissues, which makes defect restoration and marginal sealing more challenging. Highly exposed pulp horns require a minimally invasive approach to cavity preparation in order to avoid iatrogenically induced pathological responses of the pulp during caries treatment [5]. Ensuring the long-term survival of restorations in the primary dentition is essential both for the child's oral health and from an economic perspective [6]. Frequent cycles of replacement due to SCLs inevitably lead to further removal of dental tissues and ultimately to the premature loss of the tooth [7]. This risk is particularly pronounced in the primary dentition because of the unique anatomical and physiological features of the teeth of the first dentition.

The restoration of primary teeth aims to preserve the tooth in the dental arch until its natural exfoliation. They play a crucial role in a child's nutrition during the first 6–7 years of life, participate in speech development, provide structural support for the facial muscles, determine the smile and overall facial expression, contribute to aesthetics, and are important for the child's social adaptation and the quality of life. The masticatory function stimulates jaw development and teaches the child proper eating habits. In addition, pain from carious lesions may cause sleep disturbances, which can further affect overall development.

The significance of primary teeth during the early years of life, along with the faster progression of carious lesions due to the thinner and less mineralized dental hard tissues, underlines the importance of identifying and managing all risk factors associated with the occurrence and progression of SCLs. The present review aims to summarize the risk factors related to SCLs development and their clinical significance.

REVIEW RESULTS

Risk factors for the development of SCLs

The conditions and factors influencing the development of SCLs in the permanent dentition have been widely studied, whereas research specifically addressing their causes in the primary dentition remains limited [8]. All factors that promote dental biofilm accumulation or hinder its removal can be considered risk factors for the formation of SCLs [9]. This implies that any part of a restored tooth that favors plaque retention may serve as a site for lesion development. The same factors that play a role in the initiation and progression of primary caries lesions are also central to the etiology of SCLs [10,11]. The longevity of a restoration depends on the restorative material used, as well as on factors related to the patient and those associated with the dentist.

Factors related to the restorative material

Unlike permanent teeth, the longevity of restorations in the primary dentition varies significantly depending on the restorative material used [12]. Numerous studies have established that composite materials carry a higher risk of SCLs development compared to amalgam and glass ionomer cements (GICs) [10,11,13]. To a large extent, this is because composites accumulate more biofilm on their surface than other restorative materials or tooth structures [11].

An explanation for the increased plaque accumulation on composites may lie in their surface roughness; however, the literature presents conflicting opinions on this matter. Proponents of this theory emphasize the role of surface roughness, suggesting that a rougher surface provides a greater area available for microbial adhesion [14]. Other authors argue that there is insufficient evidence to confirm this association [15]. Different studies employ various polishing techniques and instruments, with differences in duration and applied pressure, which makes standardization impossible [16]. Furthermore, in the oral environment, saliva and glucans may mask the inherent differences in surface roughness characteristics between materials [17, 18].

The adhesion of microorganisms also depends on surface hydrophilicity, chemical composition, environmental acidity, temperature, and other factors [11, 18, 19]. The surfaces of conventional GIC restorations remain relatively rough even after optimal polishing, which favors microbial accumulation. However, the bacterial composition around and on these restorations does not differ significantly from that associated with composites, except that cariogenic streptococci are found in lower quantities. This is likely due to the release of fluoride ions from GICs and their interference with the metabolic processes of plaque microorganisms [19]. This evidence suggests that surface roughness is not the primary factor in the development of SCLs, although it does stimulate microbial accumulation.

Bacterial colonization on composite surfaces is further facilitated by the continuous release of residual monomers after polymerization, polymerization shrinkage, biodegradation, and the risk of mechanical breakdown of the bond between the composite and the tooth surface [11, 20, 21]. Researchers have also identified the lack of antibacterial and buffering effects in composites as an additional reason for their higher susceptibility to SCLs development [10, 11, 22].

One of the strategies for the prevention of SCLs involves influencing the metabolism of cariogenic bacteria, reducing their quantity, and inhibiting their growth within the dental biofilm and in the carious dentin beneath restorations. For this reason, in recent years, scientific attention has been increasingly focused on incorporating cariostatic and antibacterial agents into restorative materials, representing a promising approach in the prevention of SCLs.

Risk factors related to the patient

Among the risk factors for the development of SCLs related to the patient is the level of the individual caries risk [6,10,13,23,24]. According to some studies, SCLs occurs three times more frequently in individuals with high caries risk compared to those with low risk [10]. The number of placed restorations over a certain period is another individual risk factor for SCLs formation [24]. It has been demonstrated that restorations failing due to SCLs are more common in patients with a higher number of restorations in the oral cavity [24]. The number of carious lesions present at the time of restoration placement is also relevant. Children with multiple carious lesions are at greater risk of requiring restoration replacement [6]. The socioeconomic status of the family and the educational level of the parents also influence the survival of restorations [23,24]. The first two years after restoration placement are reported as the most critical for the initiation of SCLs. The main reasons include a lack of motivation from the patient and parents to change harmful dietary habits and to improve oral hygiene practices. This leads to rapid activation of existing carious lesions and the appearance of new primary and secondary ones. It is considered that one of the reasons for the longer survival of restorations in the permanent dentition compared to the primary dentition is precisely the easier motivation of adult patients to reduce harmful habits and risk factors [25].

All of this highlights the importance of the active involvement of the patient and their family. The long-term modification of a high-risk oral environment requires motivation and education toward health-oriented behavior on the part of the dentist, as well as commitment and responsibility from the patient and their parents.

Factors related to the clinical technique

The professional experience and skills of the dentist are often cited as the second most important factor influencing the longevity of restorations, including the risk of developing SCLs [10, 13, 23, 25]. Studies have shown that more experienced practitioners tend to produce restorations with greater longevity [26]. Inadequate or excessive etching, as well as errors in the application and polymerization protocol of the adhesive, may compromise adhesion and thus create conditions for microleakage [13], which is considered a possible prerequisite for the development of SCLs.

Treating children poses additional challenges with regard to strict adherence to protocols during cavity preparation and restoration placement, particularly with regard to moisture control, to which composite materials are especially sensitive. This requires additional training and careful attention to minimize the risk of SCLs development.

Factors related to the cavity class and the location of the restoration

The cavity class, location, and size of the restoration also influence the formation of SCLs. Class I and especially Class II restorations are more prone to the development of SCLs compared to other classes [11, 13, 25]. SCLs are most frequently diagnosed on the gingival margin [10,13,23]. Several reasons account for this. Maintaining the gingival margin of restorations free from biofilm represents a significantly greater challenge for patients compared to any other surface, particularly when it is located proximally. Since SCLs typically arise in areas prone to biofilm accumulation, it is logical that cervical proximal zones carry the highest risk [27].

Ensuring dryness of the operative field in this region is also challenging for the dentist due to the sensitive and multi-step procedure required for composite placement [28]. Direct visual control in this area is limited, which can lead to improper adaptation of the material and/or insufficient placement. As a result, voids may form, providing niches for dental biofilm accumulation [10, 24, 27].

Polymerization shrinkage, characteristic of composite materials (CM), can also lead to the formation of a cervical microgap, which favors the development of SCLs [24]. Occlusal forces generated during mastication are concentrated in the cervical region of the tooth and cause mechanical degradation of the tooth–restoration interface. This results in the formation of cracks, which can later develop into microgaps and microleakage [11, 13, 27].

The risk of developing SCL on proximal surfaces is particularly high in primary teeth due to their anatomical characteristics — the smaller crown height and the wide, flat contact area located close to the cervical zone of the molars predispose to caries development, as this

region is difficult to clean and prone to biofilm accumulation [29]. According to the OXIS classification, there are four types of contacts between primary molars: O (open), X (point), I (straight), and S (serrated/wavy) [30]. It has been established that the last two present the highest risk for caries development due to the potential for intensive biofilm accumulation beneath the contact area [30]. Tight contacts prevent natural saliva clearance and represent sites requiring additional effort in maintaining proper individual oral hygiene [30].

Restorations placed on distal teeth are considered to carry a higher risk for the development of SCLs compared to those on anterior teeth, as well as restorations involving the cervical proximal areas of the teeth [13, 25, 26]. Moreover, the larger the proportion of the tooth surface that is restored, the greater the likelihood of subsequent SCL formation [6, 25].

Diagnosis of Secondary Caries Lesions

The diagnosis of SCLs has always been a challenge for dental practitioners and carries significant clinical and therapeutic importance [31]. Early detection of SCLs enables the application of a minimally invasive approach, reducing the risk of subsequent excessive loss of tooth structure and financial burden for the patient [1].

Visual-Tactile Method

Although most commonly applied, the visual-tactile method has its limitations and difficulties in SCLs diagnosis, relying heavily on the clinical experience of the practitioner [32]. It does not provide reliable information regarding early SCLs, nor for those located on proximal surfaces, where such lesions most frequently develop and are difficult to detect by direct examination [33].

Radiographic Method

Bitewing radiography offers the best opportunities for detecting proximal SCL that are not clinically visible [33]. However, limitations of this method include the parents' refusal to undergo such an examination, due to what they consider exposure to ionizing radiation, the risk of misinterpretation due to image overlap, technical difficulties when performed on uncooperative children, the subjectivity in image interpretation, as well as the fact that the carious lesion must be at an advanced stage in order to be diagnosed [34, 35].

Modern Technologies

Methods based on laser fluorescence (Diagnodent), quantitative light-induced fluorescence (QLF), and optical coherence tomography (OCT) provide great potential for further objectifying the diagnosis. Nevertheless, their routine application in everyday practice remains limited due to high costs and the need for specialized equipment.

Currently, the most reliable strategy for diagnosing SCLs remains the combination of a thorough clinical examination with bitewing radiography.

Prevention of Secondary Caries Lesions

Considering the fact that caries lesion formation is influenced by multiple factors, the prevention of SCLs must also be multifactorial. It involves accurately assessing the removal of irreversibly damaged carious structures during the initial preparation in the operative treatment

of a carious lesion, the appropriate selection of restorative material, the maximum limitation of microleakage, maintenance of optimal oral hygiene, dietary counseling, treatment of existing carious lesions and periodontal diseases, and regular dental check-ups [36].

Therefore, the prevention of SCLs depends not only on the actions of the dental practitioner but also on the active participation and the behaviour of the patient.

CONCLUSION

The development of SCLs is recognized as the most common cause of failure in all types of restorations in both the primary and permanent dentition. The anatomi-

cal and physiological characteristics of primary teeth predispose them to faster and easier progression of such lesions, emphasizing the need for systematic identification and classification of all risk factors associated with their onset and progression. A number of risk factors have been linked to the development of SCLs - those related to the dental practitioner, the patient, the restorative material, as well as the type and location of the restoration. Their effective control is essential for preserving the primary dentition until the time of physiological exfoliation and for preventing the negative consequences of premature loss of primary teeth.

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