Chapter 2

CURRENT MANAGEMENT METHODS OF DEEP CARIOUS LESIONS

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INTRODUCTION

Caries is an infectious disease that causes destruction of dental hard tissues after a certain period of time, when favorable conditions occur with the presence of bacteria, fermentable carbohydrates, plaque, acidogenic and aciduric microorganisms. Bacterial metabolism by-products cause mineral loss from the tooth surface and initiate enamel demineralization. Underlying dentin will be affected if the demineralization continues to progress. In dentin tissue, demineralization is more rapid due to the high tubular structure and lower mineral content. Further demineralization of dentin results in cavitation[1].

Caries reaching the inner third or quarter of dentin are defined as deep caries and have a higher risk of pulp exposure[2]. Clinically it is impossible to measure the residual dentin thickness thereby the radiographic assessment is valid (Figure 1). Yet, to determine the deep dentin caries accurately in mm is a difficult procedure due to the x-ray distortion of the dental radiograph and generally, the dentist evaluates the depth of caries at the radiography with his/her clinical experience. However, x-ray mesh grids specialized for intra-oral films, the software programs and measurement methods can be used to show the existing carious tissue.

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Researchers have reported that the invasion of dentinal tubules by cariogenic microorganisms and thermal damage during mechanical caries removal, chemical irritation of restorative materials, or acidic agents applied to the dentin can cause pulpal reactions[3, 4]. Therefore, the residual dentin thickness, depth of caries are of great importance to avoid from these negative situations.

There are different treatment approaches in the management of deep caries to maintain pulpal vitality (Figure 2). While caries are completely removed in conventional approaches, less invasive methods are accepted today highlighting that complete removal of soft dentin may not be necessary.

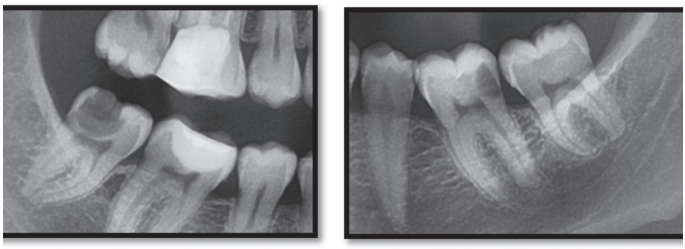

Figure 1. Radiological diagnosis of deep dentin caries

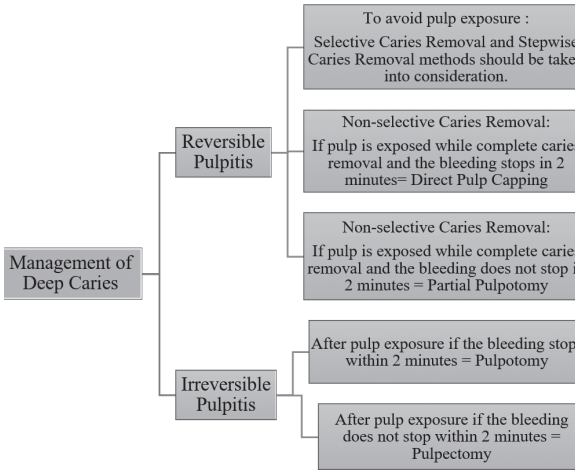

Figure 2. Management methods of deep caries

1. NON-SELECTIVE CARIES REMOVAL

In 1908, G.V. Black was claimed that it is better to expose the pulp than to leave it covered with softened dentin. Nevertheless, this approach causes excessive tissue loss and is now considered overtreatment[5].

The complete removal of softened dentin in order to eliminate both the biofilm and the microorganisms within the carious lesion was recommended in this technique. However, it is impossible to eliminate all the bacteria since a few will remain even if all soft dentin is removed. Additionally, it is repoted in several studies that bacterial counts under sealed restorations were drastically reduced[6-8]. This indicates that complete caries removal is not essential to eliminate all the bacteria under the sealed restoration.

Non-selective Caries Removal technique has some disadvantages, such as the risk of pulp expose, weakening of the tooth structure with excessive tissue removal, or reduced vitality[9]. To overcome these disadvantages, alternative strategies were developed.

2. SELECTIVE CARIES REMOVAL

In deep carious lesions, non-selective caries removal puts the pulp at risk of exposure that is why other strategies should be considered[10]. Incomplete caries removal is a non-invasive technique that allows pulp to be protected from mechanical hazards of complete excavation. Selective caries removal technique includes complete removal of the carious lesion from the cavity margins and peripheral cavity walls but limited removal from the pulpal floor[6].

The clinical assessment of carious dentin was subjective and differs from infected to affected dentin depending on the clinician. Consequently, some methods are developed to ease the selective removal of the caries lesion. One of these methods is polyamide polymer burs. Polymer burs are tougher than infect-

ed dentin, and softer than affected dentin. Thus, while removing infected dentin, the burs remain intact, and when it comes to healthy tissue, the burs will undergo deformation which prevents excessive tissue removal[11, 12].

Another method for selective caries removal was chemomechanical caries removal technique. In this technique, a solution was applied onto the caries, allowing it to soften the tissue, and scraping it off with blunt hand instruments. This technique has advantages included removal of infected dentin tissue only, absence of pain (no need for local anesthesia) and absence of negative mechanical removal effects to the pulp, due to heat and pressure[13]. However, chemomechanical caries removal methods are thought to affect the adhesion of restorative materials. On the contrary, Haak et al. stated that chemomechanical caries removal has no adverse effects on adhesion when modern bonding systems are used. They also claimed that smear layer-dissolving or smear layer-modifying bonding systems could benefit from chemomechanical pretreatment[14].

Subjective nature of clinical assessment of carious dentin led to caries dye (acid red in propylene glycol) development that can differentiate infected from affected dentin[5]. The infected dentin includes irreversibly damaged collagen fibers and dead odontoblastic processes that would never remineralize[15]. However, the deepest layer of affected dentin was hard as a result of remineralization. Caries detector dyes can discriminate these tissues. The dye-stained dentin indicates infected tissue and should be removed. Yet in some studies, it was revealed that not all dye-stained dentin was infected and dyes may lead to overpreparation[16, 17]. Although caries detector dyes have an important role in the education of undergraduates, their clinical acceptance is limited.

The major problem of selective caries removal technique is how much caries will be left in the cavity. Selective removal to leathery, hard dentin is often preferred. However, soft dentin can

be left over the pulp to avoid exposure and maintain vitality. In this cases, care must be given to terminate preparation on non-carious tissue in peripheral enamel and dentin to ensure adequate adhesion[2, 10]. The amount of residual caries is important for bond strength because adhesion depends on the type of dentin. In a study conducted by Yoshiyama et al.[18], the bond strengths of adhesives to hard dentin were significantly higher than to affected dentin, and these values were both significantly higher than to infected dentin. The lower bond strengths to affected dentin may not be crucial, since such lesions are surrounded by noncarious dentin or enamel. However, Hevinga et al. stated that the fracture strength of teeth restored after partial caries removal was significantly reduced[19]. This can be explained by the lower value of the young module of carious dentin which can lead to greater deformation in the dental restoration complex, causing increased sensitivity to higher marginal stresses and fatigue failure[20]. On the contrary, in a study conducted by Silva et al.[21], it is demonstrated that maintaining the demineralized, softened dentin tissue under the composite resin restoration had no significant effect on the development of enamel cracks and fracture strength of the restoration. Therefore, it can be concluded that there is no difference between non-selective or selective carious removal techniques on the biomechanical behavior of bulk-fill composites in the class II restorations. The reason for these conflicting results can be differences in the extent and depth of caries, cavity configurations, and the materials used.

Since, there is a lack of standardization for the degree of excavation and residual caries, investigating selective caries removal is challenging. While Lula et al.[22] and Phonghanyudh et al.[23] removed only superficial necrotic dentin from the pulpal floor and left the soft dentin, Casagrande et al.[24] removed all of the soft dentin from the pulpal floor and left the leathery dentin. Therefore a healthy comparison cannot be achieved among the current studies.

Many studies indicated that the selective caries removal technique had a significantly lower risk of pulp exposure compared with non-selective caries removal technique[9, 24, 25]. In a 3-year follow-up study, Casagrande et al.[24] reported that there was no statistically significant difference in two methods by the aspect of pulpal complications but selective caries removal group showed higher frequency of restorative failures (15.4 %) compared to non-selective technique (2.0 %). In a meta-analysis conducted by Li et al.[9], results demonstrated that the pulpal symptoms and failure of the selective technique might be comparable to that of non-selective technique, with a decreased pulp exposure risk.

Even if the clinical survival of selective and non-selective caries removal technique is quite similar, the majority of dentists prefer complete removal of caries since they think residual caries may progress or infect the pulp[26]. The advantages of minimal invasive caries removal techniques should be highlighted in dental education, and long-term clinical studies are required to convince the clinicians to the performance of incompletely removed caries.

3. STEPWISE CARIES REMOVAL

Stepwise excavation is a selective caries removal technique for deep caries management with two-visit. The necrotic and disorganized dental tissue is removed during the initial excavation, leaving soft dentin over the pulpal floor to avoid pulp exposure. The cavity is temporarily sealed with a glass-ionomer based restorative material to allow the pulp to recover and produce tertiary dentin. In the second visit, the cavity is re-opened and the residual caries are removed[27]. The aim of this procedure is to lead carious dentin to change into arrested carious dentin over time. With a calcium hydroxide based material or hydraulic calcium silicate cement, the soft and wet appearance of carious dentin becomes darker, drier, and harder[1, 28]. After several months, second-stage excavation is carried out to firm dentin which makes the procedure safer and easier.

The time interval between two sessions can affect the success of stepwise caries removal technique. When the carious dentin becomes hardened, a shrinkage of the tissue will leave a void beneath the restoration and this situation may affect the durability of temporary restoration. However, the outcome of the study conducted by Mertz-Fairhurst et al.[29], indicated that the interval between initial and final excavation is not critical and it could be appropriate to wait more than 6-12 months for the second excavation.

Even if calcium hydroxide based liner material commonly placed under temporary restorations after first excavation, as reported previously by Pereira et al.[30], the calcium hydroxide liner does not improve the short-term outcomes compared to the use of resin-modified glass-ionomer (RMGI) alone. On the other hand, some studies reported less inflammatory cells with calcium hydroxide compared to the RMGI after 60 days. Yet, they claimed no significant difference clinically[31]. RMGI can cause mild pulpal reactions when used in the treatment of deep caries; however, the inflammation decreases over time, proving that the material is biocompatible.

In the stepwise excavation technique, pulp exposure frequency is lower than one-visit selective and non-selective caries removal techniques. Leksell et al. stated that the frequency of pulp exposure during non-selective caries removal was 40% and this rate was decreased to 17.5% in stepwise caries removal technique[32]. Bjørndal et al. reported that the stepwise excavation had a significantly higher success rate (74.1%) than of the non-selective caries removal group (62.4%) due to the fewer pulp exposures (17.5%) than direct complete excavation (28.9%)[33]. However, there was no statistically significant difference in terms of pulp vitality at the short term follow-up studies with two techniques[32, 33].

Stepwise caries removal technique requires two appointments to complete the treatment and temporary restoration can result in microleakage or discomfort to the patient; furthermore, there

is a high risk of pulp exposure during the second excavation[27]. The two-visit nature of this technique may cause patients to drop out of treatment. When these disadvantages are taken into consideration, the question of whether we should re-enter these cavities has been raised. There is insufficient evidence of the need to re-enter the cavity and further excavation, whereas the studies that did not re-enter indicated any adverse consequences.

In 5 years of a follow-up study conducted by Maltz et al., selective caries removal technique (80%) presented a significantly higher success rate compared with stepwise excavation (56%). This low success rate of stepwise caries removal technique is due to the fact that some patients prone to do not attend the second appointment can negatively impact the clinical performance of this technique. If the stepwise excavation procedure was completely performed, both techniques can present similar success rates[34].

As a result of the microbiological analysis conducted by Orhan et al.[35], in the selective caries removal technique with indirect pulp capping the bacterial growth rate was 63.8% in dentin samples. The bacterial growth rate in the initial excavation of the stepwise caries removal technique was 100%, and it is drastically reduced to 44% in the second appointment. The reported bacterial growth after the final excavation was as low as 2.2%. In the direct pulp capping group, the bacterial growth rate was 25.6%. As a result, bacterial colonization has been shown to decrease the most in the stepwise caries removal technique. However, Kidd suggested that a successfully sealed restoration affects prognosis rather than residual microorganisms. Sealing the cavity interferes with the activity in the biofilm and persistent microorganism can be irrelevant. Therefore, Kidd recommends to focus on proper restoration rather than residual caries[5]. Studies showed that when radiographically detectable caries that extends into the middle third of dentin with no cavitation was placed over with a fissure sealant, the number of microorganisms was significantly

reduced[36, 37]. This fissure sealant studies also support the Kidds sealed caries approach.

In a study conducted by Alves et al.[38], residual caries in teeth treated with selective caries removal monitored for 10 years and most of the residual caries remained unchanged or remineralized. In the %77 of cases, tertiary dentin detected in the radiographic analysis. The results showed that the proper sealing of carious dentin can promote tertiary dentin deposition and induce remineralization. Unchanged or decreased lesion depth in the radiographic evaluation was the evidence of arrested caries. However, some researchers claimed that leaving soft dentin over the pulp may lead to inflammation and necrosis[39, 40]. Even if caries is expected to be arrested with the sealed restoration without access to fermentable carbohydrates, the microorganism in the affected dentine is dominated by asaccharolytic anaerobic bacteria that may derive nutrients from proteins and glycoproteins from the demineralized collagen of dentin and the pulp tissue fluids.

The minimal invasive caries removal techniques are important since it is well documented that the success rate decreased when the pulp exposed. Al-hiyasat et al. stated that the success of direct pulp capping was 60% after 3 years and it was only %33.3 if the expose occurred during caries removal[41]. Therefore direct pulp capping was only successful when the pulp exposed traumatically or mechanically. If pulp expose occurs during caries removal, it is considered infected and partial pulpectomy was the treatment of choice.

Atraumatic restorative treatment (ART) is another minimally invasive caries removal technique aimed to arrest the caries progression. After removal of the carious tissue with hand instruments, the subsequent restoration with glass-ionomer cement is completed. The survival of ART restorations ranges from 93% and 62% and this technique can be applied in non-clinical settings with low cost[42]. In a study conducted by Singhal et al. microbial counts in cavities submitted to non-selective, selective caries

removal and ART and reported that the microbiology of the ART technique resulted in a greater reduction of *Streptococcus mutans* and *Lactobacillus* spp. counts as compared to non-selective and selective techniques in which caries removed by using burs. The explanation of this could be that removing caries by using rotary instruments can cause bacterial invasion into the dentinal tubules. Since the carious tissue was removed with hand instruments in ART technique, residual microorganisms were low[43]. However, the restoration longevity was decreased in ART due to the inadequate mechanical retention as a result of used hand instruments' nature.

The comparison of deep caries management techniques is challenging due to multi factors that can affect success rates. Factors such as the materials used, patient-related factors (age, systemic diseases, oral hygine and diet habits), the depth and condition of caries can affect the pulpal prognosis and restoration success. In addition, the lack of adequate randomized controlled split-mouth studies in the literature and the lack of standardization among the current studies also prevents us to assess the techniques properly. Due to the ethical difficulties, setbacks in patient follow-up studies and lack of histological investigations, the qualified studies in this subject are quite a few. Therefore, further studies are needed to discriminate the advantage and disadvantages of each technique and to decide appropriate technique to particular case.

RESULTS

In deep carious lesions, to maintain the pulp vitality was the initial goal of the clinicians. If the residual dentin thickness was unreliably thin, alternative caries removal techniques should be considered as selective or stepwise caries removal. Every caries removal technique has advantages and disadvantages compared to one another. However, if the proper case was selected, adequate sealing was achieved and biocompatible materials were preferred, the restoration success will be improved.

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