

# Current trends in the conservative treatment of deep-caries lesion with risk of pulp exposure

Betina Paganini da Silva,<sup>1</sup> Mayara Simão Gama,<sup>1</sup> Apoena Aguiar Ribeiro<sup>2</sup>

<sup>1</sup>Department of Specific Department of Specific Formation, School of Dentistry, Universidade Federal Fluminense (UFF) Nova Friburgo, RJ, Brazil

<sup>2</sup>Department of Diagnostic Sciences, School of Dentistry, University of North Carolina, Chapel Hill, NC, USA

• **Conflicts of interest:** none declared.

## ABSTRACT

**Objective:** to present a review of the literature on the current state of the art of minimal intervention and conservation of hard dental tissues and pulp vitality in teeth with deep caries lesion and risk of pulp exposure. **Material and Methods:** we searched the databases PubMed and SCOPUS, using the descriptors dental caries in dentin, deep caries lesion and conservative treatment, between 1960 and 2018. **Results:** of the 888 articles initially identified, 52 were selected following the inclusion and exclusion criteria. **Conclusion:** there is evidence that the current conservative techniques of stepwise excavation and selective caries removal prevents pulp exposure and maintains pulp vitality, thus improving the prognosis of these teeth. However, because they are innovative techniques, although presenting evidence-based scientific support in the English literature, no articles were found in Portuguese language, making it difficult to access and increase the use of these techniques as a routine by dentists in Brazil.

**Keywords:** Dental caries; Dentin; Dental pulp; Dental pulp capping; Dental pulp exposure.

## Introduction

Dental caries, even today, is the most prevalent disease around the World<sup>1</sup> and is regarded as a public health issue by the World Health Organization.<sup>2</sup> It can be defined as a localized dysbiosis or disease, resulting from bacterial activity in the biofilm<sup>3</sup> and characterized by a dissolution of the dental structure by acids formed from the fermentation of dietary carbohydrates, especially sucrose.<sup>3,4</sup> Preventing the development of such disease, as well as controlling existing lesions, shall essentially stem from the control of biofilm,<sup>5</sup> associated with a less sucrose consumption.<sup>6</sup> Nonetheless, once the carious lesions have already developed, their stages and presence of activity within the lesion must be assessed before planning the treatment, as each stage and feature of the carious lesion requires a different management.<sup>7</sup>

The conventional treatment of caries lesions is characterized by the removal of all infected (decomposed) and affected dentin, to eliminate all cariogenic activity and to leave a hardened mineral base for restoration.<sup>8</sup> This is a concern, particularly in the case of deep carious lesions, where the risk of pulp exposure is an aggravating aspect for the maintenance of pulp vitality. Thus, avoiding the pulp exposure has a great impact on the prognosis regarding the longevity of affected teeth and reduces the cost of dental treatment.<sup>9,10</sup>

As the contemporary dentistry is ultimately focused on minimal intervention, caries treatment have acquired a more conservative and preventive character.<sup>11</sup> In cases of deep carious lesions, with risk of pulp exposure, alter-

native treatments aimed at preserving hard tissues, and pulp vitality have been widely encouraged. This because much is known, currently, about the pathogenesis of caries in dental tissues and the curative potential of the dentin-pulp complex. In this way, contemporary and conservative techniques were developed and there is, today, scientific evidence of their success. Thus, the gradual or stepwise excavation and the selective caries removal are proposals, with scientific evidence, of ultraconservative treatment techniques for deep carious lesions.<sup>12</sup>

However, despite the vast scientific evidence of success, there is still lack of articles, in the national literature, that show these conservative techniques and the current state-of-art of minimal intervention and conservation of hard dental tissues and pulp vitality in teeth with risk of pulp exposure. Therefore, this article aims at reviewing the literature and presenting current conservative techniques, to guide the clinician to minimize the risk of pulp exposure in deep carious lesions and to maintain the vitality and integrity of teeth affected by deep caries.

## Material and Methods

Searches were conducted in the databases Pubmed and SCOPUS, using the following descriptors: dental caries in dentin, deep dental caries, deep caries treatment, and conservative treatment, from 1960 to 2018. Figure 1 shows the diagram of selection and exclusion of the articles included in this literature review.

Of the 888 articles initially identified, 326 were excluded because they were duplicates. Then, through reading the ti-

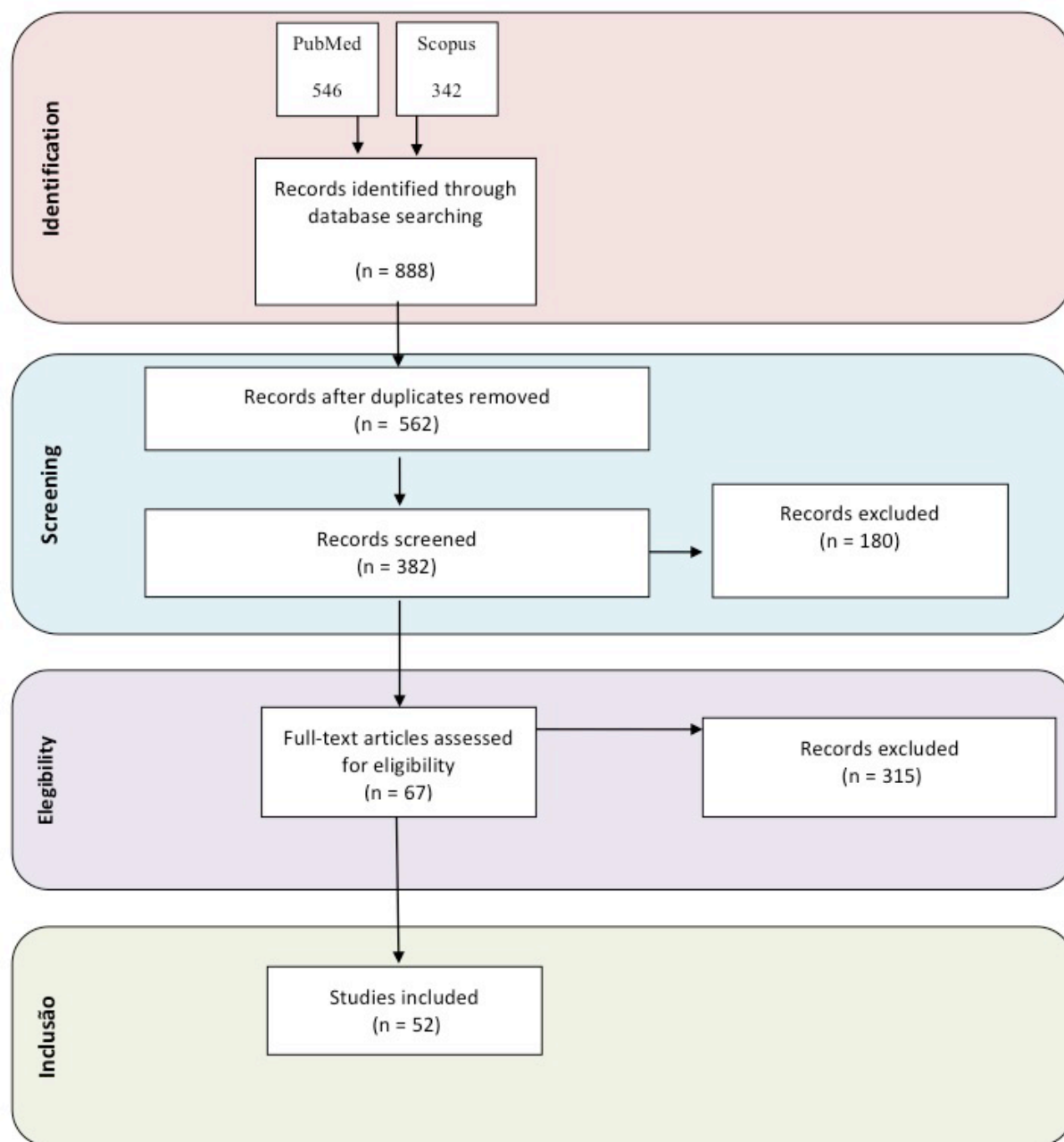


Figure 1. Flowchart for selecting the articles used in this literature review

tles, 180 articles were excluded because they met the exclusion criteria, namely: articles on shallow or medium lesions in dentin, direct pulp capping, pulpotomy, pulpectomy, studies on animals, *in vitro* studies, and those that did not belong to the subject of interest. Of the 382 articles selected for reading the abstracts, 315 were excluded based on the same criteria. Therefore, of the 67 articles remaining, read in full, 52 articles in English and Portuguese were selected, following the predetermined inclusion and exclusion criteria – including the record of study approval by the local ethics committee –, to conduct this review.

## Literature Review

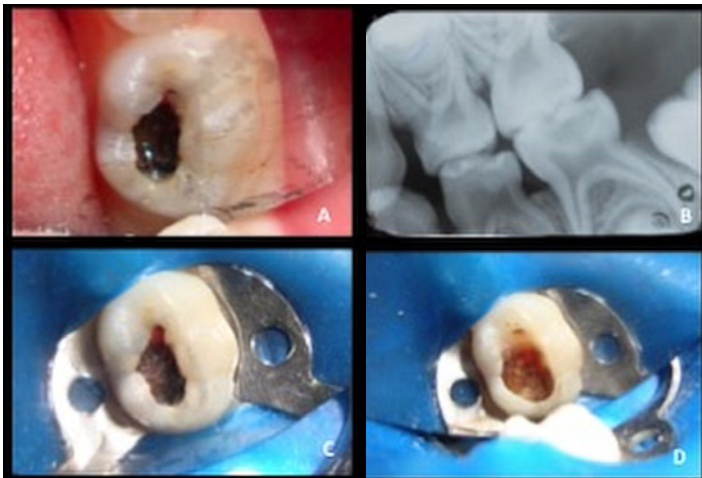
The treatment planning of caries lesions shall aim at: (1) inactivating/controlling the carious process, (2) preserving the hard dental tissue, (3) preventing the repetitive restorative cycle, and (4) preserving the tooth for as long as possible.<sup>13</sup> When in dentin, carious lesion is histologically characterized by the formation of layers with different characteristics (Figure 2): (1) the most superficial layer, which is characterized by a necrotic zone, followed by a layer of infected, decomposed dentin (2), with high bacterial counts. The underlying layer (3) is made of affected, demineralized dentin, and is followed by the last layer of reaction or sclerotic dentin (4).<sup>14</sup> Layers of necrotic and infected dentin are

characterized as a superficial layer with extensive demineralization, degenerated collagen fibers and negative odontoblastic processes, non-physiologically remineralizable and strongly infected. Affected dentin layer is characterized by intermediate demineralization, healthy collagen fibers and live odontoblastic process, in addition to being physiologically remineralizable.<sup>15</sup>



**Figure 2.** Clinical picture of carious lesion affecting dentin, with the formation of 4 distinct layers: (1) necrotic dentin; (2) infected (or decomposed) dentin; (3) demineralized (or affected) dentin; (4) reactionary (or sclerotic) dentin. Image kindly provided by Prof. Dr. Aline de Almeida Neves

Traditionally, the indirect pulp capping technique is commonly indicated for treating deep carious lesions. Such therapeutic procedure is defined by the total removal of necrotic, infected and affected tissues, until one finds a hardened dentin that offers resistance to be removed by manual or low-rotation instruments (Figure 3). Then, a calcium hydroxide coating is usually added to induce the formation of tertiary dentin, thus avoiding pulp aggression when making the definitive restoration in the same session.<sup>16</sup>



**Figure 3.** Clinical sequence of indirect pulp capping technique in single session. a) initial clinical aspect; b) initial X-ray; c) tooth after rubber dam placed for restoration; d) total removal of the infected dentin. Source: Apoena de Aguiar Ribeiro. Treatment of deep carious lesions in deciduous teeth. *PRO-odonto prevenção*. 2012;6(2):9-37. Rights for the use of images granted by Atmed Panamericana Editora Ltda.

The advantage of the indirect pulp capping technique is the fact that it can be conducted in a single session, being indicated mainly to child care due to decreasing the amount of dental consultations and treatment costs.<sup>17</sup> However, its main downside is that, due to being a less conservative technique, due to the need to leave only the dentin tissue of leathery, hardened consistency, it presents greater risk of pulp exposure, leading to a less favorable treatment prognosis due to possible pulp exposure and loss of pulp vitality.<sup>18</sup>

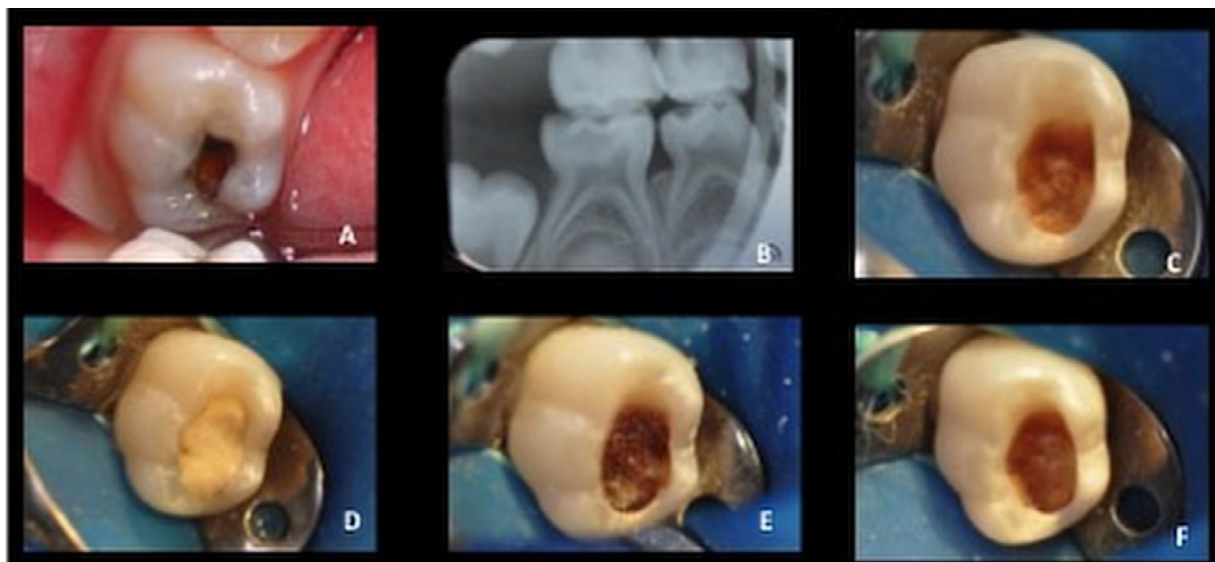
Currently, this technique is regarded as over-treatment because, with the increased knowledge on the histopathogenesis of dentin caries and on the healing potential of the dentin-pulp complex, the treatment of deep caries should only be applied to stop the lesion progression and to stimulate the dentin reaction through sclerosis and repair.<sup>13,19</sup> Currently, this may be achieved by the ultra-conservative treatment of deep carious lesions.

The conservative treatment of deep carious lesions at risk of pulp exposure aims at removing the superficial necrotic dentin and only part of the infected dentin during the acute phase of the process, followed by placement of a coating material that fosters the bactericidal or bacteriostatic action and the sealing of the cavity.<sup>20</sup> In the literature, two different types of ultra-conservative treatment are described for deep carious lesions: (1) stepwise excavation, (2) selective caries removal. The two treatment options are described below:

#### • Stepwise Excavation

Stepwise excavation is defined as a conservative treatment for deep carious lesion, where only part of the infected dentin is removed, throughout two or more sessions in a time interval – hence the term “stepwise”.<sup>20</sup> Such interval is for inducing the formation of tertiary dentin (through physiological processes of the dentin-pulp complex) and for reducing the amount of bacteria within the lesion, in addition to enabling the complete removal of the carious tissue, thus minimizing the chances of pulp exposure.<sup>21</sup>

The clinical protocol of the stepwise excavation consists of the total removal of the necrotic and infected (decomposed) dentin of the surrounding walls (layers 1 and 2, presented in Figure 2) and only partial removal of this same dentin of the bottom of the cavity, followed by coating with a calcium hydroxide paste base and sealing of the cavity with Zinc Oxide and Eugenol Cement or Glass Ionomer Cement. After 4 to 6 months, this cavity must be reopened, with the total removal of the sealing material, so that a new excavation of the remaining infected dentin may be performed (Figure 4). If it is not possible to remove all infected dentin and leave the bottom of the cavity only with affected dentin (layer 3, shown in Figure 1), a new cavity sealing should be placed and subsequent appointments for reopening may be scheduled every 4 to 6 months.<sup>22</sup>



**Figure 4.** Clinical sequence of the treatment through stepwise excavation technique. a) initial clinical aspect; b) initial X-ray; c) cavity after the first excavation. Six months after: d) tooth after rubber dam placed for restoration; e) cavity after removal of temporary filling; f) total removal of the infected dentin. Source: Apoena de Aguiar Ribeiro. Treatment of deep carious lesions in deciduous teeth. *PRO-odonto prevenção*. 2012;6(2):9-37. Rights for the use of images granted by Atmed Panamericana Editora Ltda.

One of the advantages of this technique is the lower possibility of pulp exposure in deep caries, mainly when compared with the indirect pulp capping technique. In addition, it allows the reduction of bacterial load between sessions and the physiological recovery of the dentin-pulp complex, through the production of tertiary dentin.<sup>8,23-25</sup> Leksell *et al.*<sup>26</sup> verified that, by using the stepwise excavation technique, there was a lower rate of pulp exposure (17.5%) in comparison to the conventional removal of carious dentin (indirect pulp capping), which exposure rate was 40%.

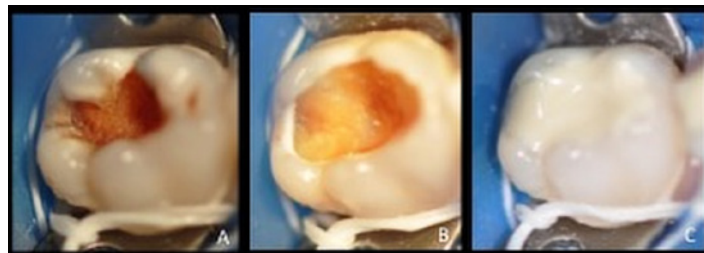
However, the stepwise excavation technique has some disadvantages, such as an additional step for reopening the cavity, which can cause problems in the pulp due to the increased risk of exposure, thus damaging its vitality. Another disadvantage is due to the risk of loss of the temporary sealing material between appointments, compromising the formation of tertiary dentin and, consequently, the lesion inactivation. In addition, since it requires an extra-visit by the patient, dentist should be aware to indicate it only to those patients who would collaborate with subsequent consultations for review and cavity reopening.<sup>27</sup>

#### • Selective Removal of Carious Tissue

The selective removal of carious tissue consists of the total removal of the infected and affected dentin of the surrounding walls of the cavity and the partial removal of the softened central dentin (infected dentin), leaving part of it in the bottom of the pulp wall (similar to the first step of the stepwise excavation technique). Thus, after the selective removal of part of the infected dentin from the pulp wall, a base with Calcium Hydroxide paste-paste might be applied (albeit not essential) and part of the cavity is filled with a

layer of resin-modified glass ionomer cement. Finally, the cavity is restored with direct composite resin, in the same session, i.e., without re-entrance in the cavity (Figure 5).<sup>28-31</sup>

Such technique became feasible due to the evolution of



**Figure 5.** Clinical sequence of the selective caries removal technique a) initial clinical aspect; b) partial removal of the infected dentin; c) direct composite restoration

adhesive materials, which ensure satisfactory clinical results of marginal sealing, even with the infected dentin remnant in the bottom of the cavity.<sup>32</sup> This is because the axial walls are free of carious dentin, so sealing is effective in preventing the remaining bacteria (in the affected dentin at the bottom of the cavity) to have access to nutrients, not favoring bacterial survival, thus significantly reducing the bacterial population within the carious lesion.<sup>33</sup> Thus, for the success of this technique, all the softened carious tissue must be removed (necrotic, infected and affected dentin) from the axial walls of the cavity, to ensure proper sealing of it with an adhesive material, aiming the inactivation of the carious lesion.<sup>33</sup>

The reduced cost and the benefit of the decreased risk of pulp exposure are its main advantages of this technique<sup>34</sup> since it does not need additional visits to the dentist, being less costly for the patient and even facilitating, mainly, the treatment of children.<sup>35</sup> However, as this is a recent technique, its disadvantage is that it requires more longitudinal

studies, even though it already shows positive results in research performed with permanent and primary teeth.<sup>12,36-40</sup>

## Discussion

The discussion on the amount of carious tissue to be removed in deep cavity lesions is not new and it aims to evaluate the success of the treatment and, mainly, the maintenance of the tooth longevity through the reduction of the pulp risk of exposure.<sup>40-42</sup> In 1859, Tomes wrote that “it is best to maintain a layer of carious dentin to protect the pulp than have the risk of sacrificing the teeth.” Nonetheless, in 1908, Black registered that “it is best to expose the pulp than leaving it covered with softened dentin.”<sup>34,3</sup>

Since then, the complete removal of the softened, affected carious dentin (or indirect pulp capping) has been considered an essential step in the treatment of caries, and it was assumed that the success of the restorative treatment depends on the complete elimination of bacteria.<sup>44</sup> However, even today, there is no definitive clinical diagnosis equipment to define when to stop the removal of carious dentin tissue, therefore, this criterion shall be defined by the dentist. Since the traditional knowledge advocates that the removal of carious dentin should be performed until the total removal of the softened dentin, this procedure ends up extending the cavity preparation not only horizontally but mainly vertically, towards the dental pulp.<sup>20,45</sup>

However, there is current scientific evidence that indirect pulp capping often leads to pulp exposure<sup>26,46</sup> and, therefore, conservative approaches have been proposed to manage deep carious lesions in permanent and primary teeth, aiming at repairing the dentin by the sclerosis of dentinal tubules and production of tertiary dentin.<sup>3</sup>

Reactional changes due to the treatment with partial removal of infected dentin and stepwise excavation were investigated by several authors.<sup>30,38-42,48</sup> Maltz *et al.*<sup>30</sup> evaluated 32 permanent teeth at risk of pulp exposure, in patients aged from 12 to 23 years. The stepwise excavation technique was carried out, with total removal of carious tissue from the surrounding walls and partial removal of the caries in the pulp wall, leaving the softened, infected dentin at the bottom of the cavity. The teeth were sealed with calcium hydroxide as base and modified zinc oxide and eugenol cement (IRM). After 6 to 7 months, the teeth were reopened, with total removal of the temporary material, and then restored with direct composite resin. They observed that there was a change in the physical characteristics of the dentin after the time interval, as it was dry and, in 80% of the teeth, the dentin became hard. In 16.7% of the teeth the dentin was leather-looking and in only 3.3% it remained soft, thus showing that, even before the incomplete removal of infected dentin, it is possible to stop the lesion progression by the formation of tertiary or sclerotic dentin.

Regarding the effectiveness of these techniques in preventing pulp exposure, comparative studies between total removal (indirect pulp capping technique) and partial removal (stepwise excavation technique) of carious dentin have shown that the stepwise excavation resulted in less pulp exposures in comparison with complete direct excavation (a difference ranging from 11.4% to 22.5%).<sup>10,18,26,51</sup> After years of follow-up, there is a significantly higher success rate with stepwise excavation – being success defined as a non-exposed pulp with tooth vitality and without apical radiolucency.<sup>24,52</sup>

However, among more conservative professionals, there is always the question about microorganisms present in the infected dentin and that were left at the base of the lesion, near the pulp. The lesion will not continue to progress? The knowledge that the lesion stops progressing when the cavity is closed, even if it still presents viable microorganisms, is scientifically established since the 1940s.<sup>49</sup> Clinical and microbiological studies, when analyzing the selective caries removal and the stepwise excavation treatments highlighted that the reopening step the reopening step, for the total removal of the remaining carious tissue left in the cavity, can be dismissed. This because the proper sealing of the cavity may promote beneficial changes in deep carious lesions, even in the presence of infected dentin. This reinforces the current scientific approach that the re-entry phase can be excluded, and the treatment may be held in a single session.<sup>8,41,42,50</sup> The recent microbiological study of Singhal *et al.*<sup>41</sup> compared the microbial counts among cavities subjected to total or partial removal of caries, showing that the progression of the caries lesion is paralyzed when the cavity is closed, even if living microorganisms are left within the cavity. Other clinical and microbiological trials also came to the same conclusion, strengthening the approach of conservative techniques for deep caries at risk of pulp exposure, without the need of a step for reopening the cavity.<sup>18,30,41,43</sup>

These studies were the basis for the design of the selective caries removal technique, i.e, without the cavity reopening step. However, for this technique to be successful, it is essential that all carious tissue must be removed from the axial walls of the cavity, ensuring its proper sealing with an adhesive material, to control the progression and promote inactivation of the carious lesion.<sup>30,41</sup> Such technique is feasible due to the evolution of capabilities of adhesive materials, which ensure satisfactory clinical results of marginal sealing, even with the infected dentin remnant at the bottom of the cavity.<sup>20,32,33</sup> This because the satisfactory sealing of the cavity prevents the entry of nutrients for the bacteria remaining in the carious tissue, not favoring bacterial survival and significantly reducing the population within the carious lesion.<sup>32</sup> Thus, the selective caries removal, albeit an innovative approach, presents high success rates in maintaining

the viability in permanent and deciduous teeth.<sup>12,38-41</sup>

Recent studies also compared the stepwise excavation with selective caries removal and reported high rates of success, specially in the selective removal technique.<sup>12,38-41</sup> In the study of Maltz *et al.*<sup>38</sup>, the success rates were 95.45% for the selective caries removal and 80.85% for stepwise excavation after one year of follow-up. Maltz *et al.*,<sup>39</sup> in 2012, also showed that, after two years, the success rates were 91% for the selective caries removal and 69% for stepwise excavation technique, suggesting that the selective caries removal treatment promotes higher longevity. Also, in a 6-year longitudinal follow-up study, Jardim *et al.*<sup>12</sup> showed that the success rate of the treatments through selective caries removal was much higher than the stepwise excavation technique (60% and 32%, respectively).

Another important point of discussion is regarding the longevity of restorations performed on the remaining carious dentin tissue. Franzon *et al.*<sup>52</sup> monitored, for 2 years, 120 primary teeth with deep caries lesions, submitted to selective removal or indirect pulp capping, to compare the longevity of restorations performed and the rate of prevention of pulp exposure. Pulp exposure occurred in 1 and 15 of the teeth treated with selective caries removal and indirect pulp capping, respectively. However, the survival rate of restorations after 24 months was 66% for selective caries removal and 86% for indirect pulp capping. Selective caries removal carried out in occlusal-proximal restorations showed a significantly lower rate of success. Thus, the implementation

of selective caries removal prevented the pulp exposure in primary teeth and, consequently, the need for more invasive treatments. However, this technique showed lower longevity for the direct composite resin restoration in comparison to the indirect pulp capping, suggesting that restorations after selective caries removal must be monitored over time, specially when they involve two or more surfaces of the tooth. Ribeiro *et al.*<sup>32</sup> showed, through scanning electron microscopy, the presence of a altered hybrid zone formed on the carious dentin; however, limited information is available about the impact of this over time.

## Conclusion

Considering the literature consulted, we concluded that the conservative techniques of stepwise excavation and selective caries removal features a lower pulp exposure rate. Among these, the selective caries removal showed better clinical performance and greater longevity. Thus, these current conservative techniques should be used to minimize the risk of pulp exposure and to maintain the vitality and integrity of teeth with deep carious lesions. However, as these are innovative techniques, no articles on the topic were found in the scientific literature in Portuguese – even though there is plenty scientific support in the literature in English –, which may justify the lack of information about the use of these techniques in the routine practice among dentists in Brazil.

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## Mini Curriculum and Author's Contribution

1. Betina Paganini da Silva – DDS. Contribution: literature search, article reading, initial writing of the manuscript. ORCID: 0000-0002-5466-2304
  2. Mayara Simão Gama – DDS. Contribution: literature search, article reading, initial writing of the manuscript. ORCID: 0000-0003-4696-1512
  3. Apoena Aguiar Ribeiro – DDS, MS and PhD. Contribution: conception, guidance and final writing of the manuscript. ORCID: 0000-0001-7702-6178
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### Corresponding Author

**Apoena Aguiar Ribeiro**

E-mail: apoena@email.unc.edu

