Chapter 4

Are the Approximal Caries Lesions in Primary Teeth a Challenge to Deal With? — A Critical Appraisal of Recent Evidences in This Field

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1. Introduction

Approximal surfaces have been pointed as a challenge regarding the control of caries lesions in primary teeth, specially due to the larger area of contact between adjacent teeth and limited salivary access [1, 2]. In addition, children can present less dexterity to using dental floss and depend on parent's collaboration to remove interproximal dental plaque [3]. Therefore, poor compliance to flossing by children [4] seems to contribute to make the arrestment of approximal caries lesions more difficult. Consequently, identifying and understanding attitudes towards flossing are very important tasks to aid health professionals for flossing orientation and its incentive [4].

Several evidences have been published recently as promising alternatives in order to deal with approximal caries lesion in primary teeth and minimize the effects of poor compliance with flossing and/or repair eventual irreversible dental decay caused by caries progression.

Minimally invasive interventions have been proposed to caries lesion management, comprising early detection, preventive procedures and minimal invasion [5]. This approach also proposes to minimize the discomfort of patient [6], specially to deal with pediatric patients' dental anxiety and fear [7]. However, even considering minimal invasive treatments, there are operational differences among them that could interfere on children's discomfort and acceptability. Indeed, when exploring options for dental treatment, not only the efficacy/effectiveness

but also the cost-efficacy/effectiveness and the patient's discomfort/satisfaction should also be comparatively investigated for available approaches.

Based on the exposed above, this chapter aims to present the particularities of dealing with approximal caries lesions and make a critical appraisal concerning effectiveness/efficacy, applicability, utility and clinical relevance of recent published studies and their findings. In this way, we expect to permit the clinicians to choose the best option for treating initial and advanced approximal caries lesions in primary teeth basing your decision-making process on relevant scientific evidences.

2. Approximal caries

Caries lesions (clinical signs of the disease) are developed on the biofilm-tooth interface [8-10] and the key factor of their formation is the presence acid-producing biofilm of the tooth surface [11]. Usually, minerals from oral fluids and tooth are in balance. However, when a tooth surface has biofilm accumulated for some period, changes in pH occur, caused by biofilm bacterial metabolism [8]. These pH fluctuations at biofilm-tooth interface may cause tooth mineral loss when the pH is decreasing (demineralization) or mineral gain when the pH is increasing (remineralization) [12]. When there is a prevalence of demineralization over remineralization, mineral loss is observed and this leads to a caries lesion [8, 13]. Thus, caries lesions start with mineral loss from the tooth surface and, if the biofilm is not removed, they progress until cavitation and tooth destruction.

Considering that the demineralization/remineralization processes occur on the biofilm-tooth interface, special attention should be given to the main biofilm stagnation areas, as occlusal surfaces, approximal surfaces and smooth surfaces along the gingival margin. These areas are relatively protected from mechanical wear by tongue, cheeks, abrasive food, and toothbrushing [13].

Since mechanical removal of the stagnated biofilm does not occur, the lactic acid produced by this biofilm acts on enamel and may cause demineralization. As the enamel is constituted by hydroxyapatite crystals, separated from each other by small intercrystalline spaces filled with water and organic material [14], the mineral loss due to caries results on an increase of these intercrystalline spaces, increasing the enamel porosity [15]. The mineral loss is higher in the subsurface of caries lesions and the surface layer thickness of the lesions ranged from 35 to 130 μm. The maximum mineral content in this layer corresponds to 74% to 100% of that of sound enamel [16]. This histopathological process is observed clinically as the formation of white spot lesions. The mentioned mineral loss results in the loss of translucence of the enamel and the opaque appearance of the white-spot lesion [17]. On the approximal surfaces, these lesions developed between the contact point and the gingival margin, resulting in a kidney-shaped white spot lesion (Figure 1). This area is the one most prone to biofilm accumulation on approximal surfaces (Figure 2).

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Figure 1. Approximal caries lesions. Note the shape of this lesion, located contouring the contact point, which is the area where the biofilm usually stagnates.

Figure 2. Biofilm accumulation on approximal surfaces. Note other dental surfaces are clean, but the biofilm remains stagnated in approximal areas.

The progression of enamel caries takes place along the enamel prisms, and in the approximal surfaces results on a conical shape [18] (Figure 3 and 4). If the plaque stagnation on caries lesions does not succeed, the lesion may reach the dentinoenamel junction and progress into the dentin [11] (Figure 3). The progression of an enamel lesion into dentine in primary teeth is faster than the observed in permanent ones [19].

There is no consensus in the literature about how does the progression of caries lesions when it reaches the dentinoenamel junction [11, 20]. Nevertheless, it is known that in lesions that reach the dentinoenamel junction, demineralized dentine is present, as part of the progression

of enamel lesions [21]. On the other hand, the level of bacterial invasion is very low [22], especially because there is no cavitation. Therefore, it is expected a lower progression compared to cavitated lesions [23]. As dentine is composed of about 50% of mineral [24], caries progression into dentine tends to be faster than in enamel. As the less demineralized areas are the intertubular dentin composed of a matrix of collagen reinforced by apatite, the demineralization process tends to follow the direction of dentine tubules, resulting in the typical histology of dentine caries lesions, as you can see in Figure 3.

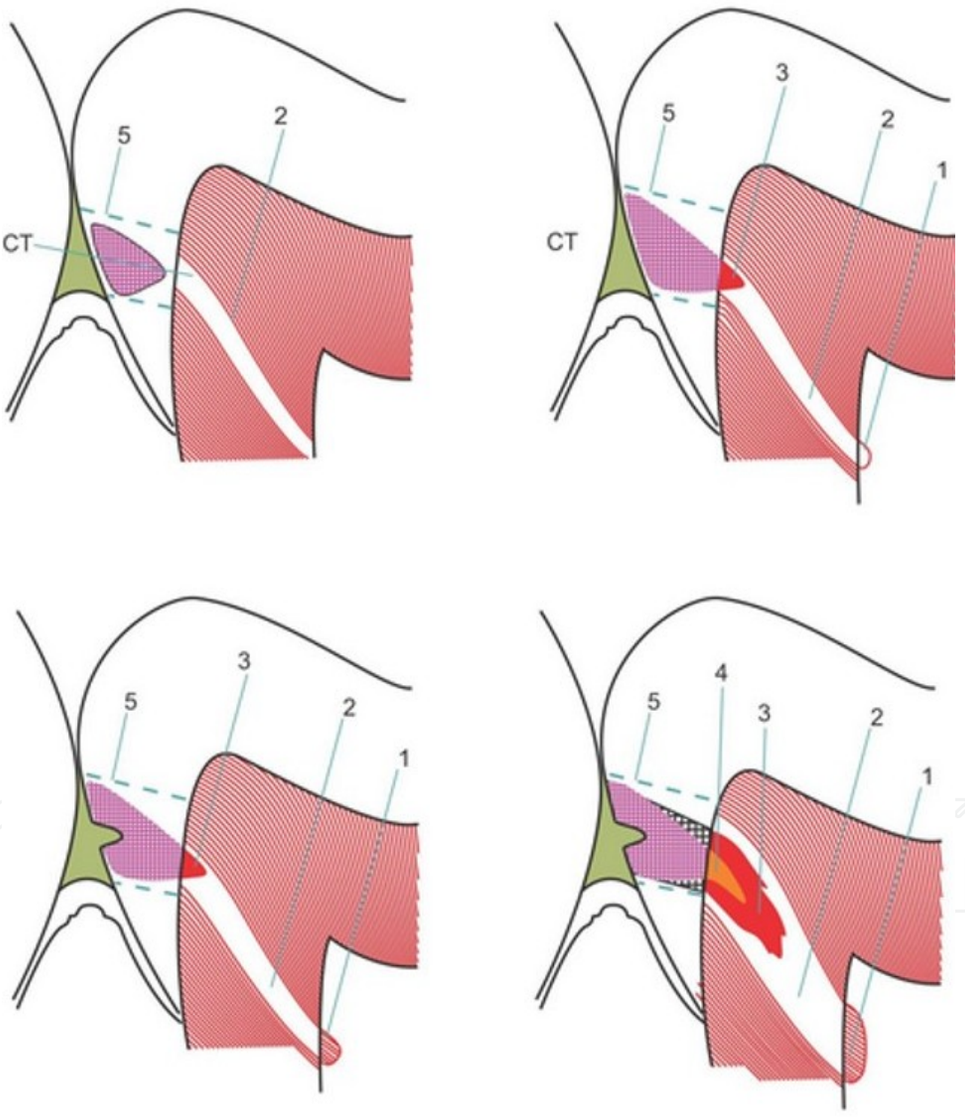

Figure 3. Schematic diagram of approximal caries progression. Different numbers symbolize different areas observed during caries lesion progression. (1- tertiary or reparative dentine, 2 - dentine tubules, 3- affected layer of carious dentine, 4-infected layer of carious dentine 5- enamel lesion) - adapated from Fejerskov et al., 2008 [14].

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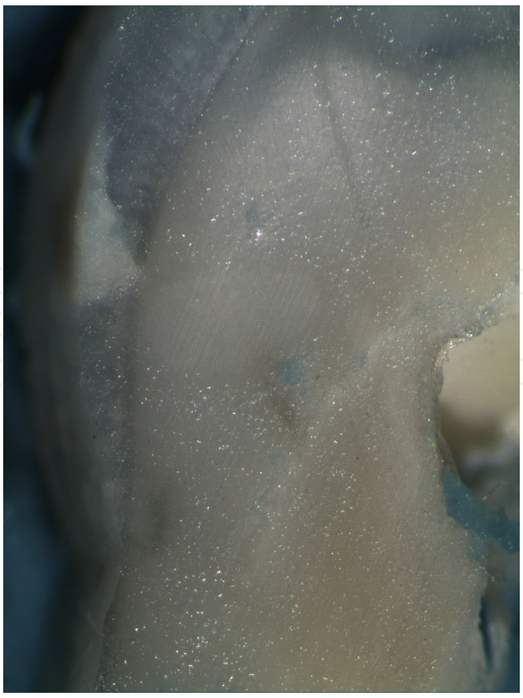

Figure 4. Histological exam of an enamel caries lesion. Note its conical shape, since progression follows the interprismatic spaces.

Substantial demineralization into dentin may be observed despite the absence of cavitation [25]. Nevertheless, if caries lesion progresses continuously into dentine, demineralized enamel may collapse and the intact surface may become cavitated. Thus, bacterial invasion into enamel and proteolytic action of bacterial enzymes mainly on the collagen may occur. If the biofilm stagnation is not controlled, an increase of the cavity size and further biofilm invasion could be expected [26]. When the cavity is present, a most infected dentine could be expected [23], which contribute to faster caries progression.

Two altered zones of dentine could be found in a dentine caries lesion: a superficial infected and a deeper affected layer [27] (Figure 3). The infected dentine consists of irreversibly acid-demineralized dentine, with its collagen degraded and highly contaminated with bacteria [28]. The affected dentine is only minimally infected and has potential to repair under suitable conditions, since their collage structure is maintained [29, 30]. Clinically, the main difference between these zones is the consistency due to the amount of collagen degradation observed in each one. The infected dentine tends to be soft and easily removed with excavators, while the affected dentine is usually harder [29] (Figure 5).

Since the progression of caries lesions is slow, the dentine may react in order to minimize the chance of occurrence of pulp exposition/inflammation. Therefore, highly mineralized peritubular dentin is secreted and reduces the tubules diameter, decreasing the dentine permeability and the chance for bacterial contamination [11]. This reaction is usually started since the caries lesion reaches the dentinoenamel junction. However, even considering the slow progression of caries lesions and pulp mechanisms for preventing pulp damage, it is not always possible to avoid the pulp exposure. When the reaction takes time to succeed, this

(a) (b)

Figure 5. Clinical aspect of infected (a) and affected dentine (b) in dentine caries lesion.

highly mineralized dentine (Figure 6), also called as sclerotic dentine [31], is found in the bottom of the cavities, showing a hard consistency and usually a darker coloration.

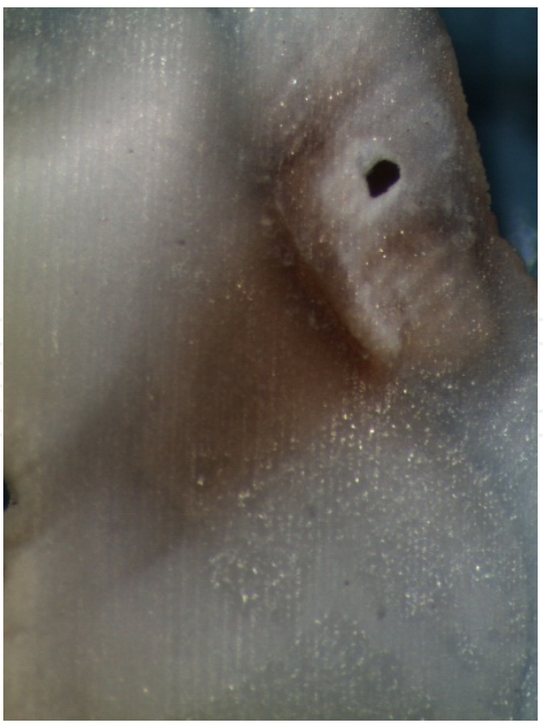

Figure 6. Histological appearance of sclerotic dentine. Note the different appearance of dentine, evidencing the hypermineralization of peritubular dentine.

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Despite the stage of caries lesion, the presence of biofilm at the tooth surface determines caries progression [32]. Since this biofilm may be controlled, the lesion may be arrested. Therefore, both for non-cavitated and cavitated lesions, the inactivation of caries lesions would be possible, when the control of the biofilm is possible [33]. Since the biofilm control is achieved, the redeposition of mineral is facilitated. This mineral gain tend to reduce enamel porosities [34, 35]. Therefore, active lesions generally exhibits a more porous surface layer than the inactive lesions [16]. In addition, the surface wear/polishing may occur and differences in enamel surface roughness may occur [34, 35]. Due to that, active and inactive lesions tend to be different due to enamel porosity and surfaces wear/polishing (Figure 7). Besides, dentine caries may also be arrested. In these cases, there is an increase in the mineral content in the surface layer of the dentine lesions. The arrested dentine caries lesion presents more mineralized dentine, the surface is not always infected surface layer and may present sclerotic, harder

Figure 7. Active enamel caries on mesial surface of a second primary molar. Note characteristics usually associated with active lesions caused by biofilm stagnation in this area. Despite the absence of the adjacent primary molar, note the remained fragments that make the plaque removal and lesion arrestment more difficult.

Figure 8. Active dentine caries on mesial surface of a second primary molar. Note characteristics usually associated with active lesions caused by biofilm stagnation in this area. Despite the absence of the adjacent primary molar, which will permit the mechanical control of local biofilm, this lesion did not have time enough to arrest. In this situation (absence of the adjacent tooth), this lesion tend to be arrested. That is why the picture still evidences characteristics of a dentine active lesion.

consistency and, usually, dark colour [36] (Figure 8). Changes observed in inactive dentine lesions may be detected after 6 months. However, hard consistency is usually observed after total arrestment of the lesion, which generally takes years [36].On the other hand, it is worth to state that due to difficulties in controlling the biofilm on approximal lesions, few assessed lesions present the characteristic above, as we are going to discuss in further sections of this chapter (Figures 7 and 8).

3. The challenge: Controlling approximal caries lesions

Approximal surfaces of primary molars present some particularities that expose them to a greater risk of developing caries [1, 37], and, consequently, it is a challenge when controlling caries lesion is needed.

Firstly, approximal surfaces in primary teeth present a large area of contact between them, favoring stagnation of carbohydrates and hindering biofilm removing [1, 2]. Moreover, the salivary access is limited, which contributes to further reduction of the biofilm pH compared to more accessible surfaces, promoting a more acidogenic environment and propitious to the development of caries lesions [1]. In addition, the limited salivary access reduces the exposition of these surfaces to fluorides.

Despite young children usually present wider approximal spaces [38], in most children, the anatomical conditions do not allow that approximal surfaces are cleaned only with brushing, requiring the use of dental floss to remove the biofilm. Besides, the patients' adherence to using dental floss seems to be low [39], mainly regarding children, since they could present less dexterity to flossing and depend on parent's collaboration to remove interproximal biofilm [3, 40]. In fact, a systematic review showed that interproximal caries risk decrease when children's flossing is performed by professional. However, authors suggest these findings cannot be extrapolated, since flossing has only failed when used by the children by themselves [41]. A recent study of our group showed motivational issues are more associated with non compliance with flossing by children (Figure 9).

The challenge becomes even greater when the initial lesion progresses to cavitated lesion (Figure 10). In addition, the biofilm accumulates inside the lesion and it is not possible to be removed by flossing. Consequently, the dentine inside this cavity tend to become more infected [23] and caries progression is faster. Indeed, the inactivation of cavitated lesions (only by self-removal of biofilm) is usually more observed in smooth or occlusal surfaces. We usually observe that in very small cavities or very large decays, for example. On approximal surfaces, most cavitated caries lesions hardly ever present favorable conditions to be arrested (Figure 10).

For all these reasons the approximal surfaces of primary molars are the most affected by caries lesions in some populations [1, 42]. Even in regions where this is not occurring, controlling interproximal caries lesions is still a challenge, especially due to the difficulty of the mechanical control of biofilm on such surfaces. That is why many approximal lesions are active lesions,

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Figure 9. Child using dental floss. Sometimes, children present difficulties in dexterity for flossing. However, motivation is often the biggest problem.

Figure 10. Cavitated lesion on distal surface of the first primary molar. Note the plaque stagnation inside the cavity, which makes difficult the control of such lesions.

although other surfaces have presented higher rates of caries progression [43]. In fact, smooth surfaces are cleaned easily [43] and lesions are easier to be controlled [44]. Besides, the occlusal surfaces, despite their morphology, are favored by the attrition [43]. In the Figure 2, it is possible to notice the remained biofilm on approximal surface, despite presenting smooth and occlusal surfaces with absence of visible plaque, complicating the control of approximal caries, even in initial stages.

Rates ranging from 70% to 90% of approximal caries progression have been shown for primary teeth after 1 or 2-year-follow-up [45, 46]. These figures have been superior to rates found for permanent teeth [47], that is comprehensible since a faster progression is expected in these teeth [48].

Based on the rationale detailed above, it is evident that controlling approximal caries lesions is really an actual challenge in pediatric clinic. Further, we will discuss about important aspects concerning detection and management of approximal caries lesions in primary teeth.

4. How may approximal caries be accurately detected? — Difficulties and important aspects

Detection of approximal caries lesions has not been a simple task. The simplest and most accepted method for caries detection among children is the visual inspection [49]. On the other hand, it is obvious that the contact between adjacent teeth makes caries detection by visual inspection more difficult. Ideally, approximal surfaces should be examined after cleaning by dental floss (Figure 11). When assessing approximal surfaces looking for caries lesions, it is important to examine, firstly, by an occlusal view. In this view, the dentist will observe the integrity and appearance of the marginal ridge. If a caries lesion is present (usually more advanced ones), cavities (Figure 10) or shadows (Figure 12) may be seen in this area. Further, the surface should be examined by buccal and lingual/palatal view. If caries lesion reaches these areas, it may be also detected by visual inspection (Figure 13). The direct examination of this surface is rare and may only occur when the adjacent tooth is not present (Figure 14).

Figure 11. Cleaning the approximal surface before visual examination – note the use of dental floss.

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Figure 12. Approximal caries lesion evidenced by the shadow we can see above the marginal bridge.

Figure 13. Buccal view – lesion may be detected since is extended from mesial into buccal surface.

The visual inspection using a scoring visual system has shown high specificity in caries detection on approximal surfaces [50]. However, lower values of sensitivity should be expected [50]. In other words, most part of non-cavitated approximal caries, as well other several cavitated lesions, cannot be detected when visual inspection is used. Radiographs have shown to increase the sensitivity of caries detection [50, 51]. On the other hand, although some clinical guidelines have recommend taking bitewing radiographs in all children to detect caries lesions in primary molars[52], its utility has been recently questioned, since no additional benefit was observed in comparison to only the visual inspection being performed [53].

Figure 14. Direct examination of an approximal caries lesion due to the absence of the adjacent tooth.

Actually, using only visual inspection may lead to higher number of false negatives (some non-evident lesions may be missed). However, these lesions may be arrested by preventive measurements. On the other hand, the radiographs may result in higher number of false positive results, what may be worse, since it might lead to unnecessary operative treatment [53]. In addition, several non-cavitated lesions may have the radiographic appearance of a cavitated lesion (Figure 15). As a consequence of radiographic examination, they might receive unnecessary operative treatment. Weighing the pros and cons of bitewing radiographs for caries detection, it seems more useful to take bitewing radiographs in order to confirm the presence of approximal caries, in cases in which visual signs have been identified (instead of detecting non-evident caries) or to help the choice for the best option for treating an approximal caries [54]. In the last situation, radiographs may help in caries depth assessment and also, in evaluation of the periapical tissue [54].

The presence of cavities has been another concern regarding approximal caries detection, since the cavitation has been considered an important point in the prognosis of these caries lesions. As mentioned, some cavities are not detected by visual examination. Besides, radiographs do not aid in this issue, as exposed before. The temporary separation using orthodontic rubbers is an available alternative [55, 56], which permit the direct visual inspection and tactile examination of the approximal surfaces (Figures 15 to 17). This technique is well-accepted by children [49]. However, it is necessary two appointments to permit the conclusion of diagnostic using this method. Even visuo-tactile assessment of approximal surface is possible; doubts in diagnosis may remain. The inderdental space created after temporary separation is around 0.8 mm [38] and may not always be large enough to guarantee there is no cavity on the surface, nor to affirm the cavity is clinically within enamel. In fact, several dentine lesions are not cavitated. Other dentine lesions may may be associated with microcavities; however, without exposing the dentine. On the other hand, we believe that some cavitations which present radiographic image into dentine may be wrongly scored as cavity clinically restricted to enamel. This is why the limited space reached after teeth separation may be not enough to the

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Figure 15. Direct visual inspection (a) and radiograph (b) of the same surface (distal surface of the second primary molar). Clinically, we can see a white spot on the approximal surface (absence of shadows in the marginal bridge) – (a). Radiographically, we evidence a radiolucid image suggestive of caries lesion in dentine. The image might also suggest the presence of cavity (b), that is definitely not evidenced in clinical examination (a). This case represents a false-positive result for caries in dentine that could occur in some radiographic examinations.

dentist being able to actually felt the bottom of these cavities, in order to confirm if he/she is felling enamel or dentine surface. These are limitations of this method. However, since there is no other available possibility to detect the presence of cavities, we have used the temporary separation when we suspect that a cavity is present, especially if dentine involvement is confirmed by visual signs or radiographs.

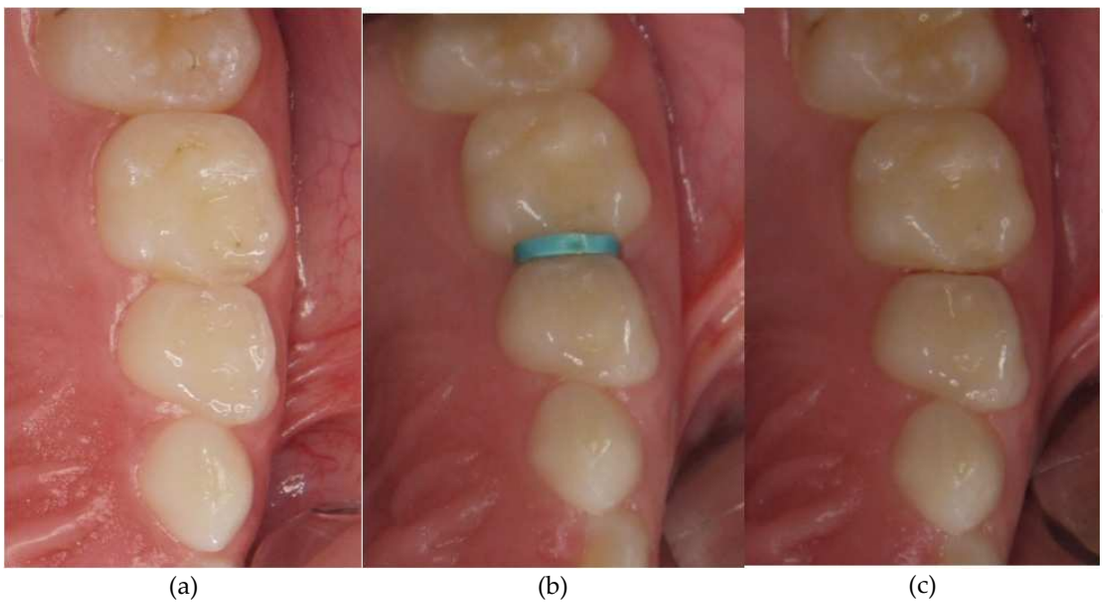
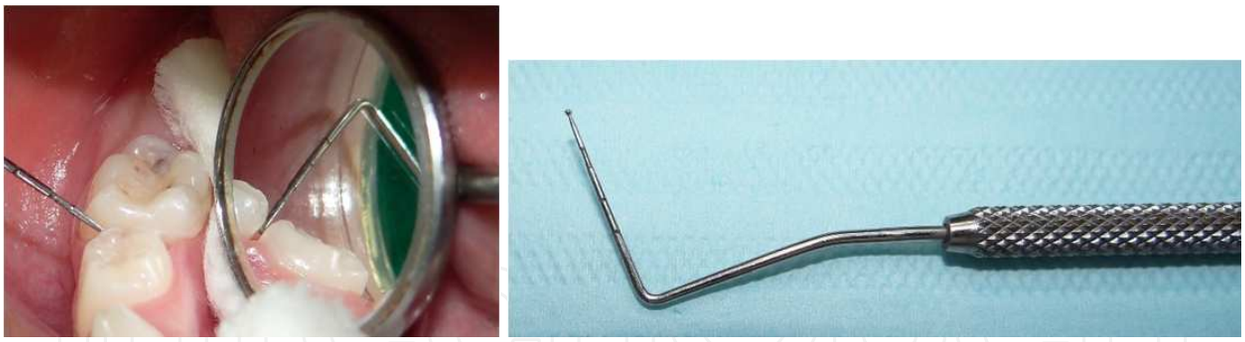


Figure 16. Temporary tooth separation using orthodontic rubbers. (a) before placing the rubber between adjacent teeth; (b) after placing the rubber; (c) after removing the rubber – note the wide space for direct examination.



(a) (b)

Figure 17. Temporary tooth separation using orthodontic rubbers – visual and tactile assessment of separated surfaces (a); WHO probe (ballpoint probe) used to tactile assessment of surfaces.

The activity status is not usually a differential in caries lesions assessment, especially in children. In fact, as exposed before, most part of detected approximal lesions tend to be active [43]. It is not impossible to find inactive approximal caries. However, especially among children, the interproximal plaque control is still very deficient and make the lesions arrestment more difficult. Thus, activity assessment is not a real concern in primary teeth. In some situations, when the adjacent tooth have exfoliated, we may observe a natural process of lesion inactivation of an approximal caries due to the possibility of controlling biofilm only by toothbrushing such area (see Figures 8 and 14).

5. Is it possible to control approximal caries lesions?

In theory, controlling dental caries in any surface is related to controlling of dental plaque over the lesion [32]. As the activity status of approximal caries is not usually a differential factor, we will not discuss it here. However, it is obvious that, if an approximal caries lesion is arrested, it would not demand any measure to be controlled. Considering this situation, we may guide the management of approximal caries lesions basically according to depth and severity, assessed during examination of caries lesions. The conceptual tree for managing caries lesions on approximal surfaces is presented below (Figure 18).

Non-cavitated approximal caries lesions tend to be easier to be controlled since there is no cavity to complicate biofilm removal. Besides, if these lesions are restricted to the enamel, they have a slower progression compared to dentine [45]. Therefore, several possibilities are available in order to controlling them, from the dental flossing to the use of resin infiltration.

Cavitated enamel lesions (Figure 19) are expected to progress faster than those which present intact surface. However, most part of these lesions cannot be detected clinically, neither by visual, nor by tactile assessment. If detected by tooth separation, both non-invasive and invasive treatments would be available for such cases, but there is no strong evidence of the best option in this case. Choosing the non-invasive treatment may permit to postpone invasive interventions. Otherwise, since the presence of cavity is detected, the use of restoration as a

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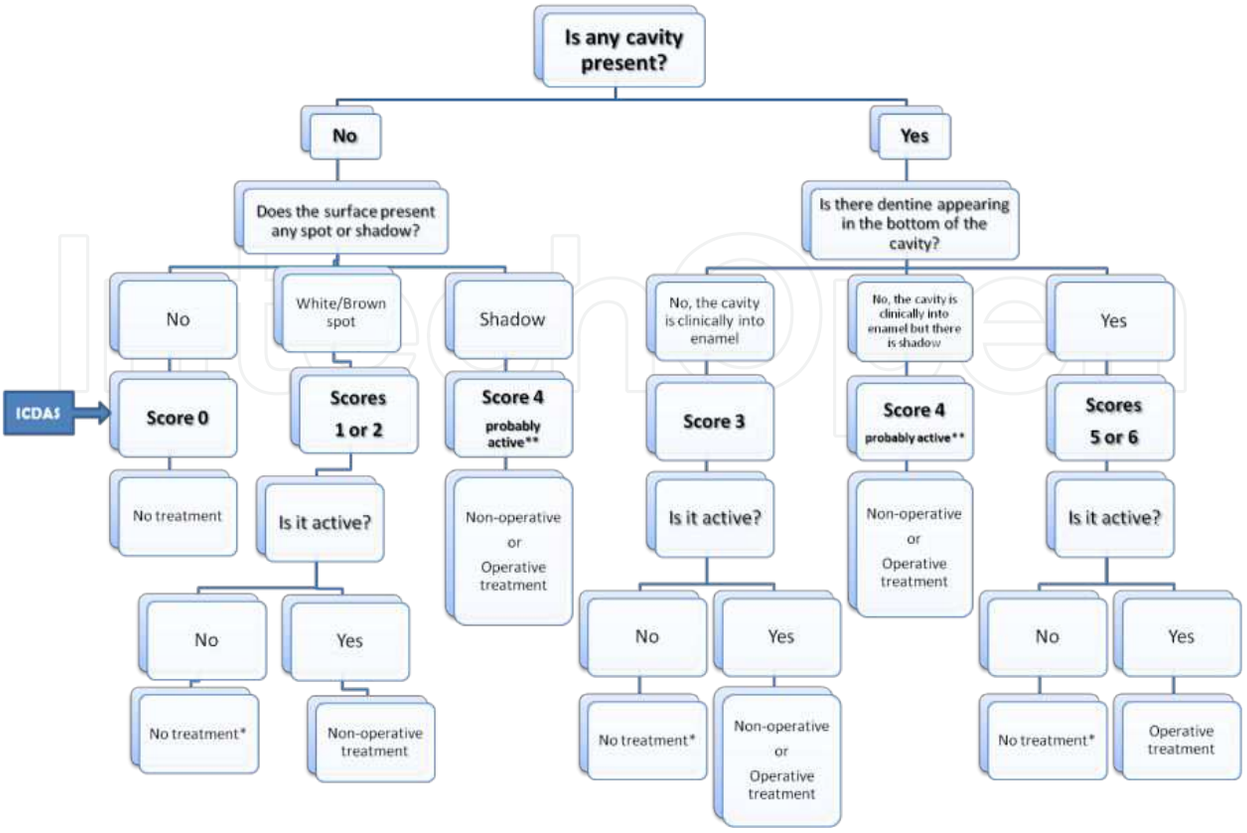

Figure 18. Conceptual tree for managing approximal caries, correlating the caries detection and activity assessment based on ICDAS and clinical decision-making. (* situations in which is usually difficult to affirm caries lesions are really inactive; ** the ICDAS activity assessment always considers lesions score 4 as probably active)

manner to control biofilm at the lesion would be necessary [57]. On the other hand, high amount of sound tissue would be acceptable in order to restore this surface adequately. Therefore, depending on patients' and professional's preferences and particularities of the clinical case, both options are possible. Considering the minimal invasive philosophy, maybe, opting for the non-restorative approach would be interesting since the children's comfort and preservation of dental structures would be maximized.

For approximal dentine caries lesions, the detection of cavities may be more relevant. If the cavitation is not easily visible or not felt by probing, the temporary separation could aid in seeking for cavities (see Figure 15). A dentine lesion progress faster than an enamel lesion. However, if the lesion is not cavitated, this progression is slower than for cavitated lesions [23], since the level of bacterial invasion is very low [22]. Based on that, we may argue the control of several outer non-cavitated dentine lesions would be possible. However, this is not so frequent. Actually, most dentine caries lesions in primary teeth are cavitated [58]. On the other hand, when the cavity is present, some approach that avoids the stagnation of the biofilm over the lesion seems to be indispensable. In this sense, any intervention which prevents biofilm accumulation on these lesions or facilitates is removal could be useful. Otherwise, it is important to clarify that mechanical removal of biofilm by flossing might not be a good choice in these cases, since the cavity may hide the plaque and interfere with caries lesion control.

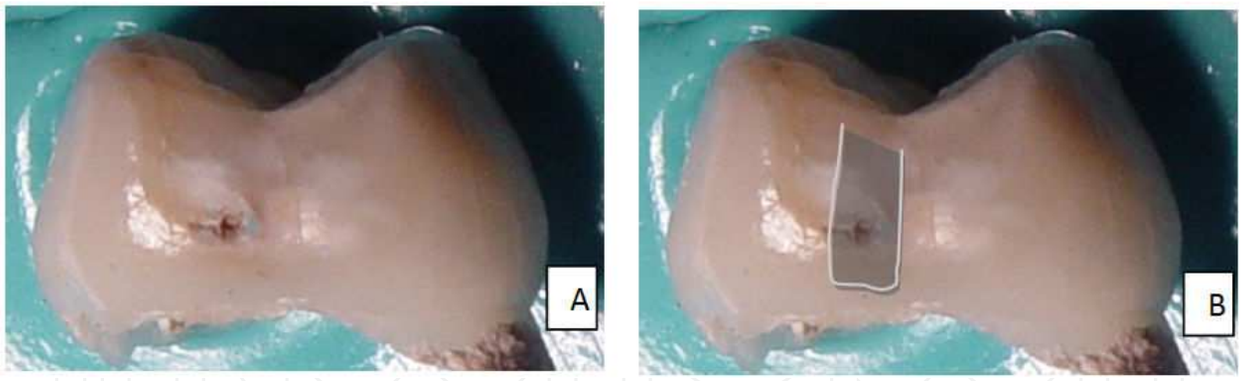

Figure 19. a) Cavitated caries lesion into enamel (direct examination). This cavity probably would not be seen when surface was assessed in the oral cavity due to the presence of the adjacent tooth. Using the temporary separation might help in detecting this cavity. Regarding treatment, we have to ponder if this lesion was detected and the option was operative treatment, a high amount of sound tissue would have to be removed. (b) Schematic representation of how accessing the mentioned cavity if the tooth was actually in the arch.

6. Options (interventions) to control initial approximal caries

Despite flossing is the most suitable method for mechanical removal of biofilm from the interproximal area [59, 60], controlling approximal caries just by flossing has not been shown to be effective [41], probably because its flossing by children and adolescents is not constant and adequate [4]. Controlling approximal caries by just flossing is a simple intervention, however, patient might be instructed and constantly motivated by professional [61]. Although dentist should never give up instructing and motivating to floss, choosing only this approach could be not enough for some approximal caries lesions. In fact, depending on children's compliance with flossing this option may not succeed, especially considering problems with motivation to flossing discussed earlier in this chapter. Thus, early interventions to initial caries lesions become even more important to arrest these lesions and prevent cavitations or lesions progression into dentine.

Initial caries lesion may be managed by remineralizing agents. A recent systematic review has shown the fluorides, in its different vehicles, present the most consistent benefit in controlling progression of initial caries lesions [62]. However, this review did not include any study which had used fluorides for approximal caries lesions in primary teeth. Actually, few studies have been performed aiming to investigate the management of initial caries in primary teeth and the evidence is inconclusive when we consider the most effective vehicle to be used, the frequence of use and the cost-effectiveness of using fluorides in primary teeth[63]. The fluoride varnish reduced in 25% the caries progression on approximal caries of primary molars [45] (Figure 20). Other fluorides vehicles, as gels and foams, have been associated with caries reduction on approximal surfaces [64]. However, they were tested in permanent teeth. The use of interdental brush or dental floss dipped in fluoride gel has been also advocated to using fluorides for approximal areas [65, 66] (Figure 21).

Another option tested for the same purpose was an association AgF followed by SnF2, resulting in a arrestment of 74% of approximal caries lesions [46]. At the moment, our group is testing

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Figure 20. Application of fluoride varnish on approximal surfaces which present initial caries lesions.

(a) (b) (c)

Figure 21. Use of fluoride gel on approximal initial caries lesions. (a) dental floss dipped in fluoride gel. (b) interdental toothbrush dipped in fluoride gel. (c) interdental toothbrush (note some natural space/separation is need for its introduction into approximal areas.

the use of the silver diamine fluoride (SDF) to control approximal caries in primary teeth [67] (Figure 22 and 23). A previous study of our group pointed to the possibility of using the silver diamine fluoride (SDF) in children for arrestment of enamel caries lesions on occlusal surfaces of permanent erupting molar [68]. As erupting occlusal surfaces, approximal surfaces challenge by making the mechanical control biofilm more difficult. In addition, some studies have shown that the SDF is more effective than fluoride varnish to prevent and arrest caries [69-71]. Even showing success since 1960 [69], its effectiveness had not been tested in approximal lesions of primary teeth. It is expected after SDF application, some staining may be seen on treated surfaces. The staining is probably caused by the precipitation of insoluble silver phosphates [72] (Figure 23).

Besides the remineralizing agents, another possibility in order to treat initial caries is sealing or infiltrating caries lesions [74]. Sealants have been used for several years in prevention of dental caries [75]. However, its therapeutic effect may be more expressive than the preventive one [76]. Sealing a caries lesion avoid its contact with biofilm, permitting its arrestment.

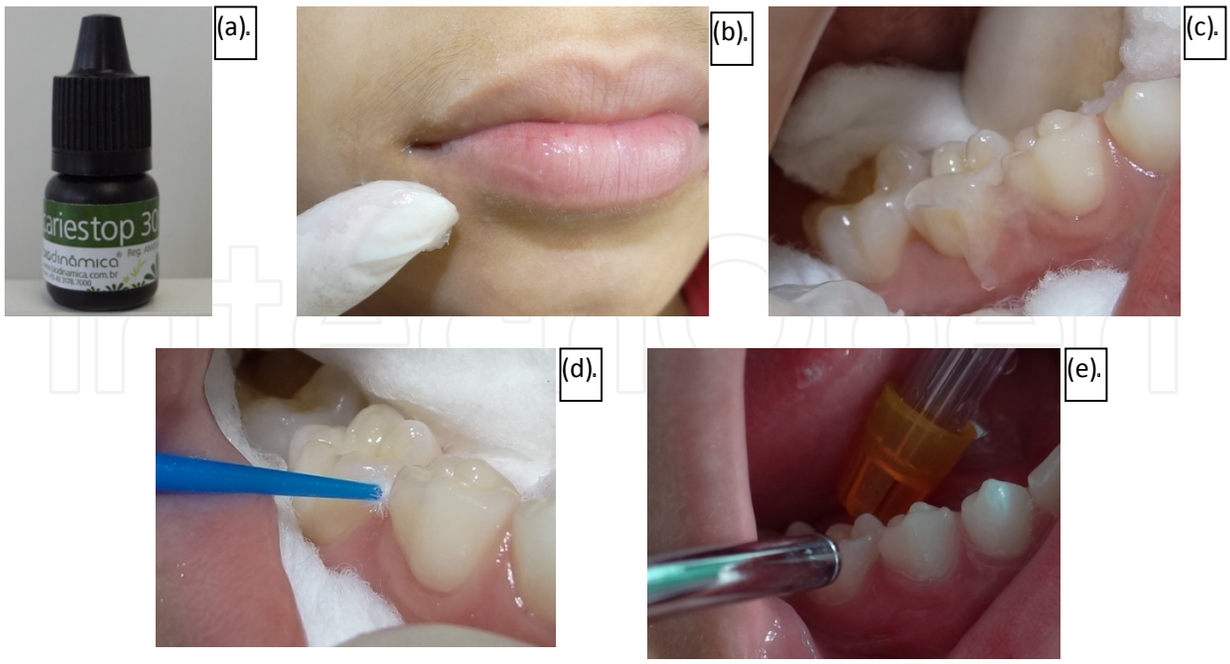

Figure 22. Application of silver diamine fluoride (SDF) in approximal caries lesions of primary teeth. (a) 30% SDF (Cariestop 30%,Biodinâmica Química e Farmacêutica LTDA, Ibiporã, Paraná, Brazil); (b) and (c) Extra-oral and intra-oral protection of soft tissues with petroleum jelly to avoid staining and mucosal irritation [73]; (d) application of SDF using a small disposable brush for 3 min – moisture was controlled by using cotton rolls and saliva ejectors. (e) washing for 30s to remove soluble final products of reaction between SDF and hydroxapatite.

Figure 23. Staining caused by the SDF application after follow-up. The staining is probably due to deposition of silver phosphate that is a insoluble salt, responsible to the dark colour when exposed to the light [72]. Note the staining is hardly visible on treated approximal surfaces.

Sealants were initially devised for occlusal surfaces, which present a complex morphology and difficult mechanical plaque removal, especially in non-motivated or collaborative patients.

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However, the principle of sealing has been extended to other surfaces in which controlling the biofilm is a challenge, as approximal surfaces [77]. The idea is the same: preventing caries lesion progression by eliminating the direct contact between the lesion and the biofilm. A previous study showed a 25% reduction in caries progression on approximal surfaces of primary teeth when sealed (comparatively to surfaces in which patients only flossed) [42]. These findings were comprehensible since when sealants are used, the poor children's compliance with flossing tends to be minimized.

Resin infiltration is other available option to "seal" caries lesions [78]. The infiltrant is a low-viscosity resin that promotes sealing into the lesion [78]. Differently from sealing, for infiltrating caries lesions, the superficial layer of caries lesion is removed by acid conditioning. Further, the lesion is infiltrated with a low-viscosity resin. Therefore, the barrier against biofilm would be created inside the lesions, instead of in the surface of caries lesions [79]. In addition, the tooth separation is not required for infiltrating caries lesions. On the other hand, if tooth separation is not performed, some doubts concerning diagnosis may remain. Besides, a kit for resin infiltration is sold containing all products used in the process and specifically designed applicators for approximal surfaces. (Figure 24). Despite these differences compared to the traditional sealants, we believe they exert similar roles in controlling caries lesions progression, since the contact between lesion and biofilm is avoided. Infiltration has been showed as an efficacious treatment for permanent teeth [79-81], but only one study was conducted in primary teeth [82]. In this study, resin infiltration was more efficacious than fluoride varnish in the arrestment of proximal lesions [82]. Although no study has compared sealing and infiltrating caries lesions on approximal surfaces of primary teeth, results in permanent teeth permit to guess that sealants and infiltrants tend to have similar efficacy when the deal is treating initial caries lesions [81].

Besides effectiveness/efficacy in controlling caries lesions, the patients' acceptance regarding the available treatments should be considered in clinical decision-making, especially treating children. Few studies have assessed patient-centered outcomes related to enamel caries lesions treatments. Sealing using relative isolation was well-accepted by most children [42]. In this study, the non-use of rubber dam was pointed as a possible concern [42]. On the other hand, when local anesthesia and rubber dam were used for infiltrating lesions in primary teeth, children reported higher levels of discomfort than when other non-invasive approaches were used [83]. Therefore, we consider that those techniques that cause less discomfort should be preferred and considered by clinicians. In addition, patient's and parents' satisfaction with treatments for initial caries lesions have not been evaluated. Staining caused by inactivation of caries lesions and/or using of SDF has not been systematically assessed. That is one of our concerns when testing the SDF as a possibility to treat initial caries [67]. Based on some preliminary findings, we believe this consequence of the mentioned treatment will not impact on patient's and parent's perceptions, especially due to the position of the surface, which hides the effect of SDF application (see Figure 23).

Finally, cost-efficacy of the mentioned treatment should be considered. More complex treatments as sealing or infiltrating caries lesions are more time-consuming [83], which will certainly lead to higher costs. Thus, even being equally effective, simpler procedures tend to

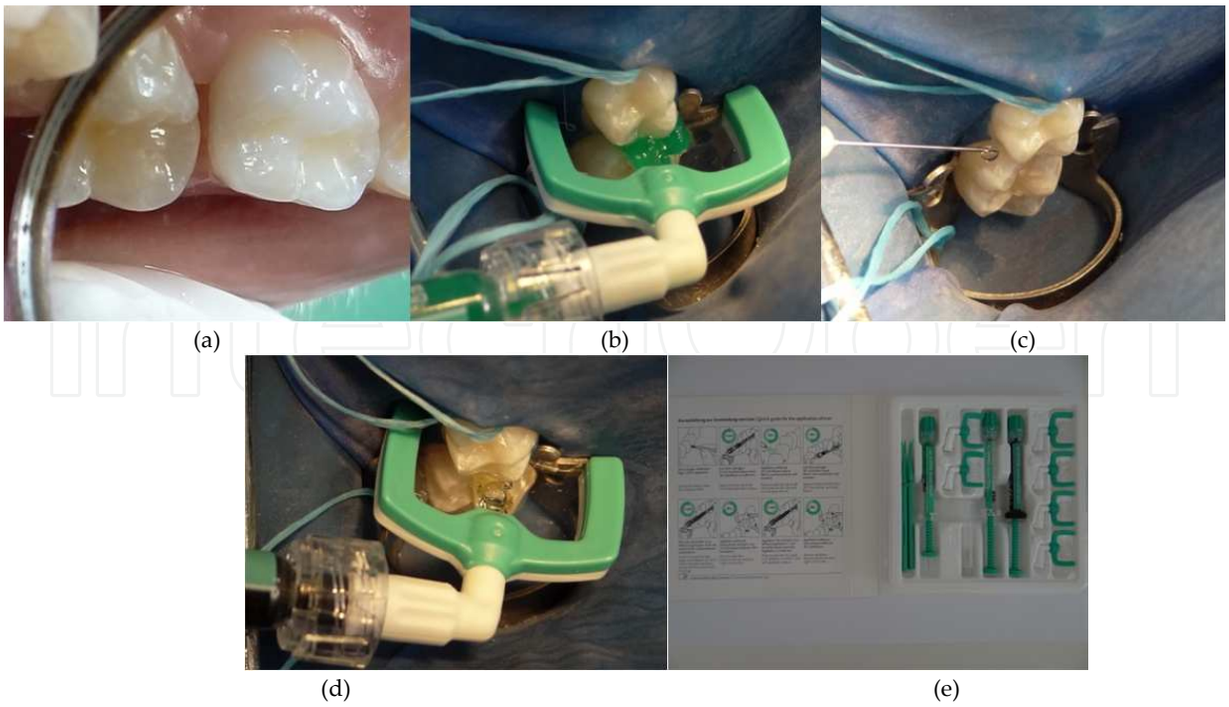

Figure 24. Resin infiltration of an initial caries lesion – (a) direct visual inspection after tooth separation - distal surface of element 54 presented a white spot lesion without any cavity. (b) After local anesthesia and adaptation of the rubber dam, 15%hydrochloric acid was applied on the lesion for 120s, followed by washing and air-drying. (c) Dehydration using 95% ethanol, followed by air-drying. (d) Resin infiltrant application on the lesion for 120s, followed by excess removal and light-curing for 40s. Further, resin is applied for more 30s and light-cured again. (e) All products used in resin infiltration are included in a specific kit commercialized for this purpose by the manufacturers (Icon® - Dental Milestones Guaranteed – DMG, Germany). *Note: For caries sealing, the steps A, B and D will be the same, but without the use of special applicators and using other materials (dental adhesives and resin sealants).*

be more cost-efficacious than complex ones. This is another point to be weighed in the decision-making process. Although our investigation is ongoing, we believe the SDF may be a more cost-efficacious/effective approach to be used in treating initial caries compared to other available treatments.

In summary, the scientific evidence regarding the effectiveness for treating initial caries on approximal surfaces in primary teeth is still scarce. However, some possible alternatives may be used until stronger evidences may be available. Additionally, it is important to consider the simplest techniques are cheaper and seem to be more accepted by children. Therefore, all these properties of the technique chosen for treating enamel caries on approximal surfaces in primary teeth should be considered conjointly.

7. Options to be used when cavitated

As discussed earlier, the greater susceptibility to caries experience of the approximal surface [1] linked to the faster progression rate for enamel to reach the dentin in primary teeth [19]

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results in a high prevalence of cavitated dentin caries lesions. These lesions need procedures that allow to arrest them and, especially, to reestablish the previous anatomy.

The treatments recommended to cavitated dentin lesion in approximal surfaces can be assigned according to depth and extent of the lesions.

Initially, when observed one cavitated lesion reaching outer dentin of approximal surface in primary teeth, without breaking the marginal ridge (see Figure 15), the utilization of infiltrating technique [82] or the sealing with adhesive system [42] or fissure sealants [77] has been proposed. These materials, as discussed for initial lesions, mechanically block the biofilm accumulation over the lesion. Previous studies have shown that both treatments seem to be good option to control caries progression in outer third of dentin [42, 82]. These previous studies included cavitated caries lesions clinically into enamel (despite their radiographic extension into dentin) [42, 82]. However, as few lesions with this severity were included in the samples, we could not draw definitive conclusions on the efficacy of these techniques or dental materials for cavitated lesions.

Sealing has been proved to be an option for small occlusal cavities exposing dentine [84]. Once more, the purpose of preventing the contact with cariogenic biofilm and enabling plaque removal from the surface instead is performing operative procedure care [84]. The same approach, if used on approximal surfaces, would avoid removal of sound enamel to access small lesions into dentine with preserved marginal bridge (Figure 25). A pilot study that compared the sealing to restoration for approximal cavitated dentin lesions showed almost 70% of sealed lesions have failed after 18 months compared to 11% of the restorations [85]. Besides, 54% of sealed lesions showed progression [85]. This finding seems to be linked with the technical difficulties in performing approximal caries sealing. Since the resin-based sealant is hydrophobic, there is a need to use rubber dam; however, sometimes there is a difficulty to maintain the work area without water (saliva, fluid) contamination [85]. Moreover, inserting both acid phosphoric and resin-based sealant into approximal cavities may have been a challenge which may justify the high proportion of observed failures [85]. Thus, although resin-based sealing represents the most conservative option to control cavitated dentin lesions, until the present moment, it is still not a satisfactory option to treat approximal cavitated caries lesions.

Depending on the size of the cavity and its location, it is also possible to improve the plaque removal from the cavity in order to promote caries lesions arrestment. This choice is especially interesting in areas in which restoration may be a greater challenge to deal than the mechanical control of the biofilm. Small approximal cavities in anterior primary teeth may be one indication for that, since restorations in these teeth may require sound tissue removal in order to access the cavity (Figure 26). Slicing has been also tested to approximal caries in posterior primary teeth [86]. Although, this technique seems to be a most conservative option for such cases, strongest evidences are necessary concerning it.

A recent systematic review showed that there is no difference concerning the choice of restorative material to treat occlusoproximal dentin cavities [87]. In this study, both conventional approaches as amalgam and composite resin were compared to Atraumatic Restorative

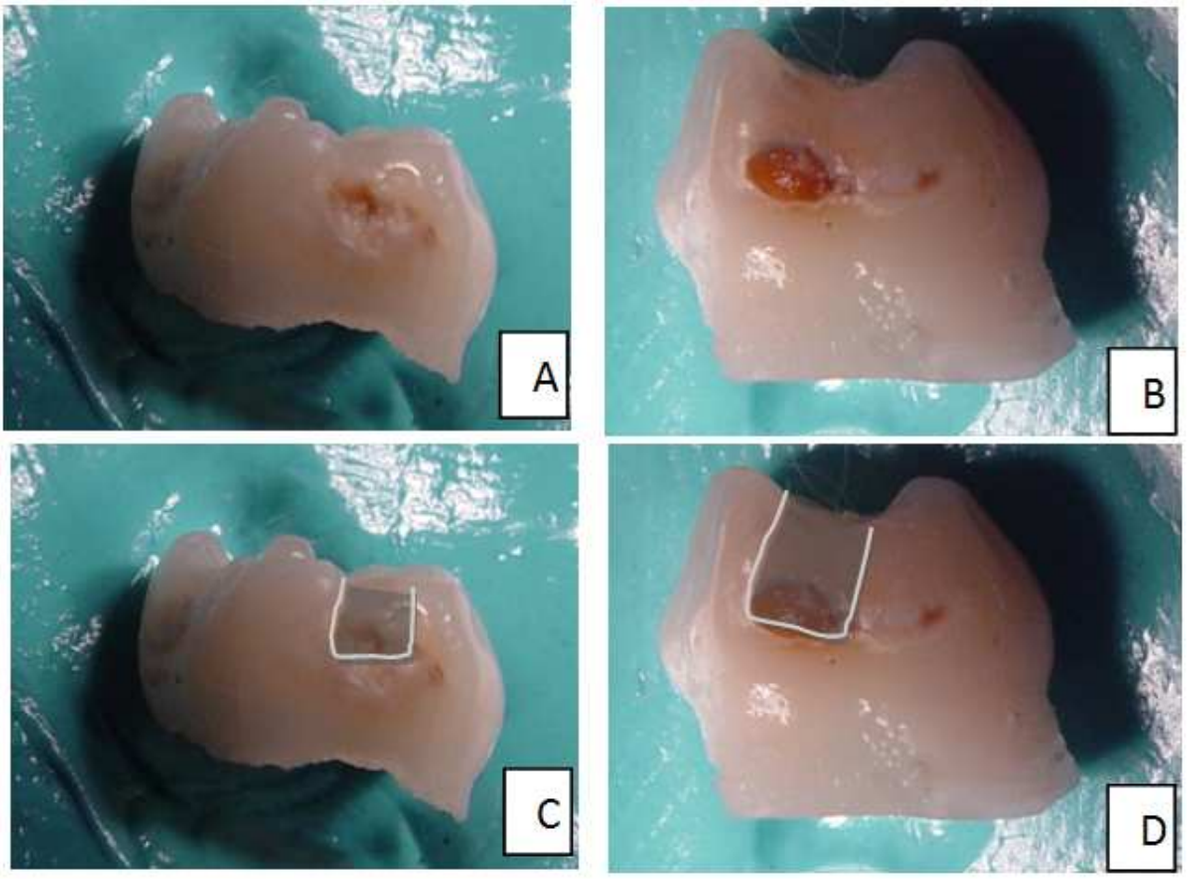

Figure 25. Cavitated dentine caries lesions (a-b). To restore these lesions, sound tissues should have to be removed, as schematically drawn (c-d).

Treatment (ART) performed with high-viscous glass ionomer cement (GIC), demonstrating similar results and satisfactory options to treating these lesions in primary teeth, until 3 years of follow up. However, when we think about the minimal intervention, which has the partial caries removal as one of its concepts, there is no reason to perform the amalgam restoration. Due to that, this procedure will not be discussed in this chapter.

Worldwide, the composite resin associated to adhesive system is, in approximately 25% of cases, the material of choice for restoring primary teeth [88-90]. This material shows satisfactory efficacy when used under local anesthesia and rubber dam, regardless of the brand of composite resin [91], demonstrating a success rate around 90% on occlusal and occlusal-proximal surface of primary teeth [92]. On the other hand, when it is considered the adhesive system, a systematic review reported that both three-step etch-and-rinse and two-step self-etching adhesive system present the best clinical performances [93]. However, this systematic review only considered the clinical trials performed in permanent teeth and these results should be interpreted with caution to primary teeth.

Some specific protocols to be applied in primary teeth in order to obtain similar results that observed to permanent teeth have been suggested. One of the proposals is shortening the etching time in dentin, for etch-and-rinse adhesive systems in order to increase the bond

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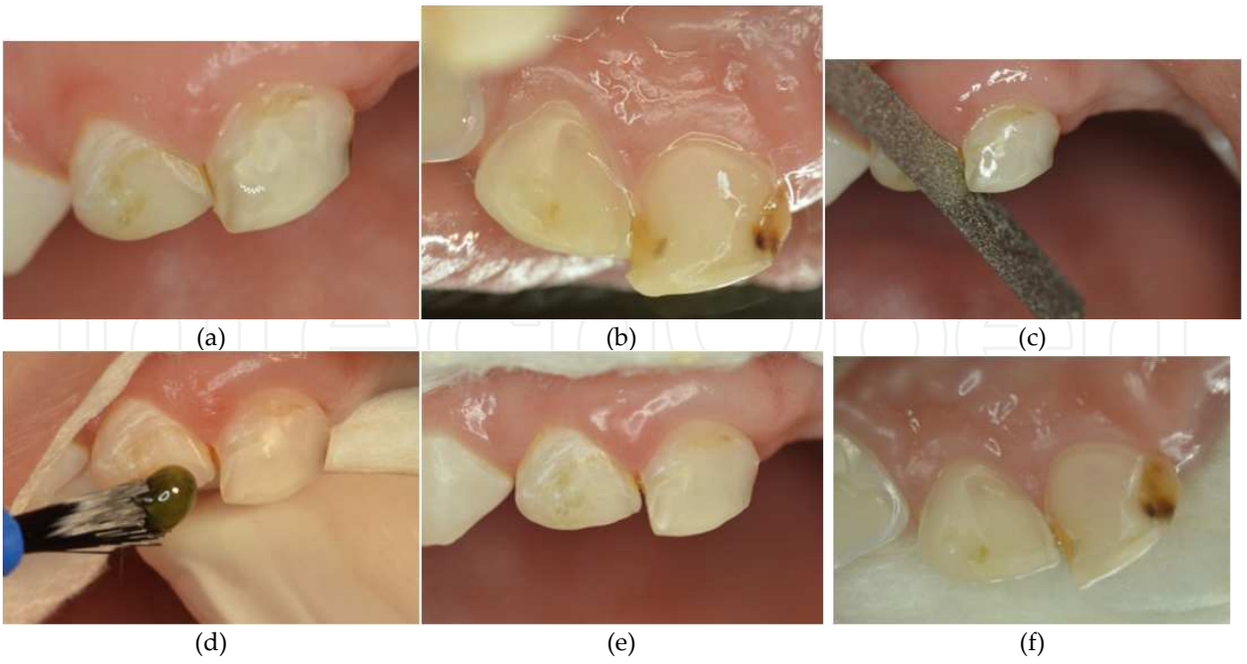

Figure 26. Small cavity on distal surface of upper primary central incisor – buccal (a) and palatal (b) view. Treatment: (c) access to the cavity to facilitate the mechanical removal of the biofilm; (d) application of fluoride varnish to enhance the remineralization. (e/f) follow-up after two weeks evidences the best control of the biofilm in the region.

stability of the restorations in primary teeth [94]. This protocol is based on previous studies that demonstrated the primary dentin is more reactive to acid etching [95, 96] and showed good results *in vitro* studies [94, 97]. Thus, the authors suggest the dentin etching of 35-37% acid phosphoric for 7 seconds before the adhesive system application [94]. Etching enamel remains in 15 seconds.

One important point to be pondered is that the main reason to failure of resin composite restorations is caries around restorations [92]. Due to that, other options of restorative materials may be considered. A previous study evidenced the effect of the resin-modified GIC restoration in prevention of secondary caries when compared to resin composite [98], probably due to fluoride release and uptake of the glass ionomer cements. The resin-modified GIC may be a good alternative, since presents a similar behavior of resin composite in clinical situation [91]. Its longevity is on average 5 years in occlusoproximal cavities [99]. However, this material contains resin monomers in its composition and may increase susceptibility to the presence of humidity compared to other ionomers. This characteristic associated to the need of a light source to polymerization of the material can be pointed as disadvantages of using resin-modified GIC.

On the other hand, similar trend regarding the protection of the margin of restorations can be observed with ART (Figure 26), since this treatment has high-viscous GIC as the material of choice. The GIC shows results such like the RMGIC in prevention of new caries lesion [100]. Moreover, studies have considered GIC as a viable alternative due to the similar survival rates compared to others restorative materials/techniques [87]. Other proprieties of GIC may also contribute to this choice, i.e., ability to chemically bond to enamel and dentine with insignifi-

cant heat formation or shrinkage, biocompatibility with the pulp and periodontal tissues and a similar coefficient of thermal expansion to tooth structure [101].

More recently, a new advantage related to GIC in occlusoproximal restoration has been addressed. Studies have claimed the contact with an approximal cavity offers a higher risk to the adjacent surfaces developing caries lesion [1]. In these cases, GIC restoration could prevent the new lesions and even to arrest the initial ones [102]. This hypothesis has been confirmed by a practice-based research, which showed that the progression rate of caries lesion on tooth surfaces adjacent to amalgam restorations was 30%, whilst to GIC restorations was only 16% [103]. These premises associated with no need of local anesthesia and rubber dam application have contributed for indicating GIC restoration associated to partial caries removal as the best option to treat cavitated lesions in children (Figure 27).

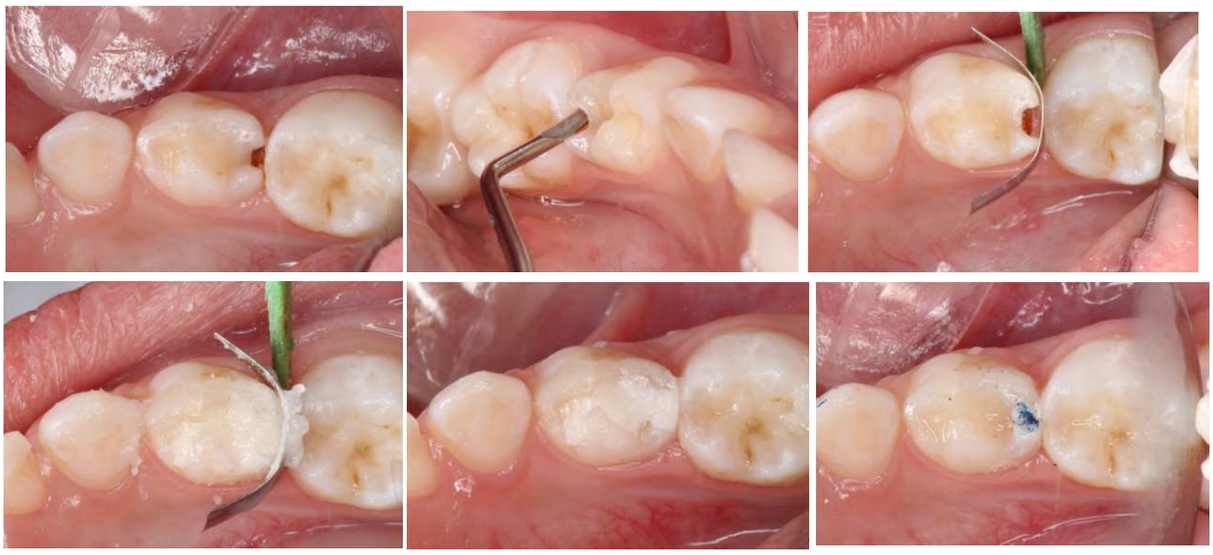

Figure 27. Step-by-step of an occlusoproximal restoration based on atraumatic restorative treatment, using partial caries removal and high-visous glass ionomer cement (GIC). (a) cavity into dentine; (b) accessing the cavity using a manual instrument; (c) preparing for restoration – to restore the contact point and avoid marginal excess; (d) after inserting the GIC and using finger pressure over the material; (e) final restoration; (f) checking the occlusal contacts. *(images gently donated by Dr. Isabel Olegario)*

8. Final considerations

It is evident, based on topics discussed in this paper, that approximal caries lesions are an actual challenge to dentists deal with. Indeed, the detection of caries lesion on these surfaces presents a duality. On one hand, the surfaces position in oral cavity makes the direct visual inspection almost impossible. On the other hand, if additional caries detection methods are used sequentially, they may lead to overtreatment in some situations (e.g. indiscriminate use of bitewings) or result in a greater doubt regarding options for treating those lesions (e.g. temporary tooth separation), since weak scientific evidences have been found for corroborat-

ing some available for clinical decision-making for approximal cavities clinically restricted to enamel.

Even if caries detection has been an overcome stage, treating approximal caries is not a simple task. Unfortunately, few strong evidences are available to support these treatments. Therefore, clinicians should try to use the best available evidences at the occasion. Based on that, we tried to contribute to clinical decision-making process joining the description of present evidences to a critical appraisal of them. We believe the critical judgment of the published evidences is crucial to guide the better clinicians' conduct to their patients.

Nowadays, the adoption of the minimal intervention philosophy has been a reality. Based on that, we have looked into evidences that may support our clinical decision-making not only based on effectiveness or efficacy of therapies used. We have also looked for manners of treating our children minimizing destruction/loss of healthy or reparable structures and guaranteeing higher levels of comfort and satisfaction to them. Due to that, we have insisted on situations in which treatments present similar effectiveness/efficacy, the simplest, the most cost-effective/efficacious or the most acceptable approaches should be preferable by dentists for treating their patients. We believe the conjoint critical appraisal of these requisites may be helpful when dealing with the challenge that approximal caries lesions in primary teeth represents.

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