# Dentin Optical Density in Molars Subjected to Partial Carious Dentin Removal

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***Aim**: This study aimed to evaluate changes in the optical density of dentin in primary molars with deep caries three to six months after they were subjected to partial carious dentin removal. **Study design**: This was a blind controlled, clinical therapy study. Standardized digitalized bitewing radiographs of 42 teeth were analyzed using Adobe Photoshop® to quantitatively determine the gray scale of the affected dentin beneath the restoration, in comparison with healthy dentin. A mixed-effects model was used for statistical analysis. The gray tone level was considered a dependent variable; the tooth region and the time, in addition to the interaction between them, were the independent variables. Values of $p < 0.05$ were significant. **Results**: During the interval between time zero and three months, the gray tone levels of affected dentin varied from $80.99 \pm 3.17$ to $98.57 \pm 3.17$; i.e., an estimated increase of 18 ($p < 0.0001$). The values for healthy dentin ranged from $118.22 \pm 3.17$ to $122.02 \pm 3.17$; i.e., a mean increase of four in the gray tone levels ($p = 0.0003$). During the interval between three and six months, both healthy and affected dentin showed similar behavior ($98.57 \pm 3.17$ to $103.32 \pm 3.20$ and $122.02 \pm 3.7$ to $126.56 \pm 3.20$, respectively) ($p = 0.0001$). **Conclusions**: Significant increments were observed in the optical density of the affected dentin after three months compared to that of healthy dentin in primary molars treated using the partial carious dentin removal technique.*

*Key words: primary teeth, dental caries, optical density*

## INTRODUCTION

The advances in cariology and our understanding of the role of dental biofilms on the caries process has changed the concepts of treatments and techniques currently employed.[1] Conventional restorative or surgical invasive treatments that remove all carious dentin from cavitated lesions no longer seem necessary, since the publication of scientific evidence supporting partial caries removal.[2,7] Less invasive and more biological approaches to treat caries have been suggested instead. In this context, partial caries removal is a suitable technique to treat cavitated caries lesions in primary teeth, thus preserving the so-called affected dentin. The affected dentin has a lower bacterial load and shows preservation of collagen fibers, thereby allowing remineralization.[2-5]

The process of remineralization depends on the maintenance of the dentin-collagen matrix for the subsequent deposition of apatite crystals.[3, 6] Clinically, the affected dentin is firm, and when using hand instruments for removal, flakes can be observed.[3, 5- 7] The portion of infected and softened dentin that contains a high bacterial concentration and lacks collagen matrix organization must be completely removed since it is not capable of remineralization. This reduces the risk of pulpal exposure as well as the need for endodontic treatment.[1, 2, 4, 5, 7, 8]

Partial dentin caries removal procedures are based on a minimally invasive philosophy.[7] This partial excavation is also recognized by the American Academy of Pediatric Dentistry (AAPD),[10] for which they use the term Interim Therapeutic Restoration (ITR). The ITR procedure involves the removal of caries using hand or rotatory instruments with caution so that the pulp is not exposed. Restoration leakage can be minimized with maximum caries removal from the peripheral region of the lesion. This technique is indicated for children with multiple open carious lesions prior to the final definitive tooth restoration, in erupting molars when isolation conditions are not optimal, or in patients with active caries.[10]

A wide range of glass ionomer cement (GIC) products with different formulations, properties, and performance levels are available for use in dentistry. A number of studies have used GIC as a

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restorative material for minimally invasive techniques such as atraumatic restorative treatment (ART),[5, 6, 8, 11,17] conservative restorations, and sealants.[9, 21, 31]

It is well known that GIC promotes fluoride release, which facilitates remineralization. Microleakage is decreased as a consequence of the excellent sealing properties of this material[1] and there is an increase in the microhardness of the affected dentin.[7, 9] Moreover, chemical analysis of the dentin of primary molars submitted to GIC restoration has revealed the presence of fluoride, calcium, and phosphorus.[7, 9, 12] A number of studies have used clinical criteria to evaluate results.[13-17]

Radiographic follow-up studies of partial carious dentin removal are infrequent and have generally involved permanent teeth.[15-17] Bitewing radiography is considered the gold standard among the auxiliary methods used to detect carious lesions and for follow-up treatment.[3, 17, 18] The gray tones of a radiograph can be quantified, especially in digital or digitized radiographs, with the help of software. The human eye is capable of seeing only 32 gray tones while the computer can identify 256 gray tones. On this scale, zero corresponds to the most radiolucent area (black) and 255 to the most radiopaque area (white).[18] Several computer programs have been used to manipulate digital images, including Adobe Photoshop®, Digora®, Image Tool®, and VixWin®.[3, 20-22]

Radiographic analysis of a tooth subjected to partial dentin caries removal reveals a radiolucent area below the restoration, which corresponds to the layer of carious dentin left on the pulpal wall. Over time, there is an increase in the dentin mineral content, which is apparent radiographically as increased radiopacity.[16] This increase can be quantitatively evaluated using either the gray tone scale of the radiographic optical density or the image subtraction technique.[20-22] The use of quantitative methods facilitates assessments of any change that may occur in the area.[20] To date, no studies have assessed the radiographic optical density of primary teeth dentin.

This study aimed to quantitatively evaluate the variations in the radiographic optical density of the dentinal region of primary molars subjected to the partial dentin caries removal technique.

## MATERIALS AND METHOD

This was a blind, controlled, clinical therapy study conducted to observe the reaction of the dentin-pulp complex following partial dentin caries removal by assessing the optical density on standardized radiographs. Clinical and radiographic follow-ups were performed at six months.

The sample consisted of boys and girls aged 4–9 years that were participants in the Social Project of the Brazilian Dental Association, Brasilia, Brazil. A total of 1878 children were evaluated. Of these, 240 required dental treatment, and only 20 patients (42 teeth) met the inclusion criteria for participation.

This study was approved by the Research Ethics Committee involving human beings of the College of Medicine, University of Brasilia, under protocol number CEP-UnB 038/2008. The Informed Consent Form was signed by the childrens' parents.

Inclusion criteria included (1) patients in good health who demonstrated positive behavior ("good rapport with the dentist, interest in the dental procedures, laughter and enjoyment") regarding dental treatment,[24] (2) the presence of primary carious lesions within the dentin ("D3 - clinically detectable lesions in dentin" according to PITTS criteria),[25] involving only the occlusal surface, and (3) patients with roots demonstrating up to two-thirds physiological resorption. Patients presenting with spontaneous pain, periapical lesions, fistulas, or any characteristics that indicated a need for endodontic treatment were excluded. Children with these conditions were referred for specific treatment. All teeth were submitted to clinical and bitewing radiography to evaluate the presence of carious lesions.

In all cases, the Interim Therapeutic Restoration was performed according to the AAPD protocol.[10] All necrotic and infected dentin was removed from the surrounding walls using sharp curettes. The removal of carious tissue was interrupted when the dentin began to flake. The cavity was conditioned with liquid from the glass ionomer for 10 seconds, then washed and dried. The material used for the restoration was high-viscosity glass ionomer restorative cement (Ketac Molar Easymix®, 3M/ESPE, St. Paul, MN, USA), mixed according to the manufacturer's recommendations. Occlusion was verified using carbon paper and excess material was removed using a Hollenback instrument. Finally, the restoration was protected with solid vaseline.

Immediately after restoration, a bitewing radiograph was taken (time zero). This radiograph was compared with other bitewing radiographs taken after three and six months. The patients used individual protective equipment (lead vest and thyroid protection) during all radiographic procedures. The present investigation used a children's bitewing positioner as an alternative device to standardize radiographs. The device was fit into the cylinder of the X-ray apparatus and a positioner flap was made.

According to this protocol, radiographs were taken at the same distance between the film and the X-ray source and at the same vertical and horizontal angles. Kodak Insight® (Carestream Health, Inc) dental film size 0 was used for all radiographs. The exposure time was 0.7 s. The film was developed, fixed, and dried in an automatic processor using a five minutes cycle. The objective was to standardize the quality of the developer and fixer, the contact time with each substance, and the temperature. All images were scanned and digitalized using a flatbed scanner with a 600 dpi resolution, and saved as 30-kilobyte jpeg files. Adobe Photoshop CS4 Extended 11.0 software was used to analyze the images using the histogram and gray tones to measure the optical density of the regions of interest.

A schematic design with 25 pixel squared areas was created to analyze the three bitewing radiographs (times zero, three, and six months), as a standardized procedure (Fig 1). The same design was superimposed on the radiographs; therefore, the same points and areas were evaluated. The radiographic optical density values for the regions of affected and healthy dentin were evaluated over time. Healthy dentin was the control area, since it was a region that had similar characteristics within the same tooth. The radiographic optical density values of the regions of affected dentin (study area) and healthy dentin (control area) were evaluated at zero, three, and six months. A single blinded operator who was unaware of the time when the radiographs were taken performed all of the measurements. The means of the values and the standard deviations were statistically analyzed.

A mixed-effects model was used for statistical analysis.[24] In this model, the gray tone level was considered a dependent variable; the tooth region and the time, in addition to the interaction between them, were the independent variables. Values of $p < 0.05$ were considered significant.

## RESULTS

Initially, the study included 20 patients (42 teeth). However, during the observation period, three patients dropped out, a sample loss of 15%. After six months, 32 lower primary molars from 17 patients (aged 4–9 years) were examined clinically and radiographically.

The affected dentin had a mean variation (gray tones and standard error) of 80.99 ± 3.17 and 98.57 ± 3.17, at zero and three months, respectively. An estimated increase of 17.57 ± 0.93 in the gray tone levels ($p < 0.0001$), equal to 21.70%, was observed. The values for healthy dentin varied from 118.22 ± 3.17 to 122.02 ± 3.17 at zero and three months, respectively. Thus, healthy dentin showed a mean increase of 3.80 ± 0.93 in gray tone levels ($p = 0.0003$) (Tables 1 and 2).

Between three and six months, both affected and healthy dentin showed similar behaviors (affected dentin, 98.57 ± 3.17 and 103.32 ± 3.20, respectively; healthy dentin, 122.02 ± 3.7 and 126.56 ± 3.20, respectively). The increase in the gray tone levels was 4.74 ± 1.05 (4.81%) in the affected dentin, and 4.53 ± 1.05 in the healthy dentin ($p = 0.0001$) (Tables 1 and 2).

A difference of 37.22 ± 4.05 in the gray tone levels was observed at time zero when the differences between the dentin regions at the three times, were analyzed separately. However, at three and six months, this value decreased to 23.44 ± 4.05 and 23.23 ± 4.09, respectively ($p < 0.0001$) (Table 3).

As seen in Figure 2, the means showed distinct behaviors over time, as evidenced by the lack of parallelism between the two curves.

**Table 1: Mean optical density values of affected and healthy dentin at times 0, 3, and 6 months.**

| | Time | Mean | Standard Error |
|---|---|---|---|
| Affected Dentin | 0 | 80.99 | 3.17 |
| | 3 | 98.57 | 3.17 |
| | 6 | 103.32 | 3.20 |
| Healthy Dentin | 0 | 118.22 | 3.17 |
| | 3 | 122.02 | 3.17 |
| | 6 | 126.56 | 3.20 |

**Table 2: Comparison of optical density values between regions of affected and healthy dentin, according to time: 0 to 3 months, 0 to 6 months, and 3 to 6 months.**

| | Time (months) | Difference Estimation | Standard Error | p value |
|---|---|---|---|---|
| Affected Dentin | 0 to 3 | - 17.57 | 0.9 | < .0001* |
| | 0 to 6 | - 22.32 | 1.25 | < .0001* |
| | 3 to 6 | - 4.74 | 1.05 | < .0001* |
| Healthy Dentin | 0 to 3 | - 3.80 | 0.93 | 0.0003* |
| | 0 to 6 | - 8.33 | 1.25 | < .0001* |
| | 3 to 6 | - 4.53 | 1.05 | 0.0001* |

*Indicates statistically significant differences.

**Table 3: Estimate of optical density values of the affected dentin subtracted from the healthy dentin values at times 0, 3, and 6 months.**

| | Time | Estimation of Difference | Standard Error | p value |
|---|---|---|---|---|
| Affected Dentin-Healthy Dentin | 0 | - 37.22 | 4.05 | < .0001* |
| | 3 | - 23.44 | 4.05 | < .0001* |
| | 6 | - 23.23 | 4.09 | < .0001* |

*Indicates statistically significant differences.

## DISCUSSION

This blind controlled clinical therapy study evaluated the partial dentin caries removal technique in deciduous teeth. There is strong evidence that leaving a layer of affected dentin reduces the risk of pulp exposure.[1] Furthermore, cariogenic bacteria, once isolated from the oral environment by satisfactory restoration, are inactivated and cause no risk to dental health.[15] There is evidence that total removal of the affected carious tissue is not necessary to control the progression of caries disease.[1, 26] This technique enables maintenance of the vitality of the primary teeth.

After the partial dentin caries removal technique was completed, the teeth were restored using glass ionomer cement. A systematic review comparing the dental fillings for the treatment of caries in primary teeth has shown that there are no significant differences in clinical performance among restorative materials.[27] According to AAPD,[5] glass ionomers are hydrophilic and tolerate a moist, not wet environment, whereas resins and adhesives are adversely affected by water. Therefore, the biocompatible proprieties of GIC were considered appropriate for the purposes of this study.

Initially, the present study included a total of 20 patients (42 teeth). However, during the observation period, three patients dropped out, a sample loss of 15%. This loss in percentage is considered acceptable.[28] It is important to assess not only the quantity of loss, but also the quality, i.e., whether the loss occurred randomly or not. In our study sample, the losses occurred "at random" and did not compromise the results. In other words, there was no association between sample loss and the children's behavior, for example.

Bitewing radiography is an additional exam that is considered the gold standard for dental caries detection and for restorative treatment follow-up. The measurement of the radiographic optical density has the advantage of transforming subtle gray tones into a quantitative measure, which is excellent from a scientific standpoint.[19] This technique does not allow any invasive assessment of changes in the mineral content over time. In studies conducted with permanent dentition,[15-17] radiographs were standardized with the help of a device made of a self-cured acrylic resin placed on the film holder. However, there are no studies in the literature regarding the use of this technique in children. The technique above was used in the present investigation, but children were not comfortable with the heat generated by the reaction of the self-cured acrylic resin. Therefore, the present investigation proposed an alternative device used for radiographic standardization: a device attached to the positioner flap to reduce biases related to the angle of the X-ray beam used. It is believed that the use of this device provided reliable results that could be easily reproduced in children. Moreover, it could be an alternative for quantitative radiographic analysis in deciduous teeth.

A comparison of our results with the literature was difficult as there were no *in vivo* studies that analyzed this procedure in primary teeth. The results showed a significant increase in the mean variation of the radiographic optical density, both in the affected and healthy dentin (Table 1 and Table 2). These data indicate an increase in the radiopacity of the treated teeth during the study period. In permanent dentition, similar results were reported after partial caries removal, despite methodological differences.[2, 19-22]

The increase in radiopacity was significantly greater in the first three months compared to the subsequent three months (Table 3). These data reinforce the findings in the literature that dentin remineralization is more intense in the three months following partial removal of the carious tissue.[30,31] It has also been reported that, after three months of partial caries removal, there is a reorganization of the collagen fiber matrix, increasing the calcium concentration in addition to drastically reducing the microbial count.[6,27] Furthermore, partial caries removal and sealing results in dentin hardening, decreased bacterial count, and dentin reorganization.[27]



**Figure 1. A schematic design with squared areas of 25 pixels was created to analyze the three bitewing radiographs (times 0, 3, and 6 months).**

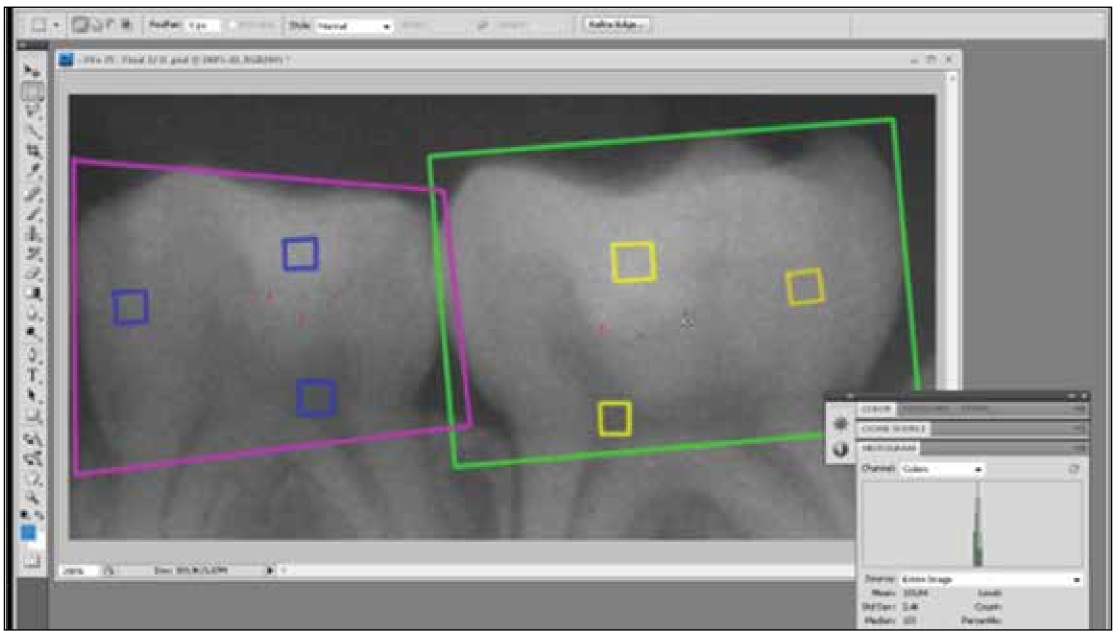
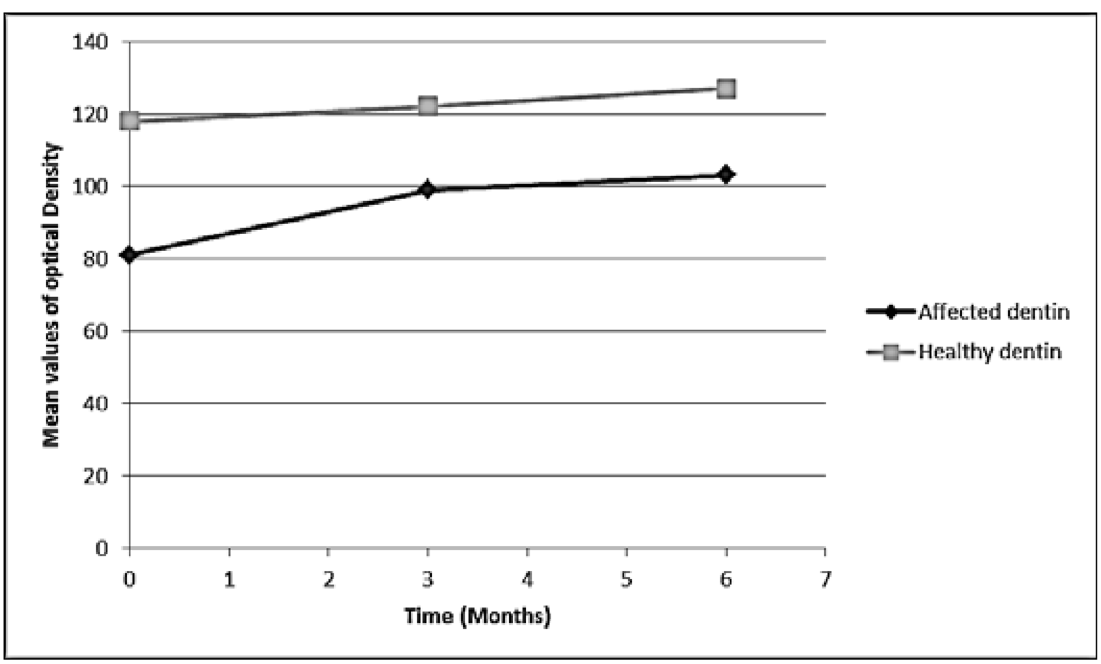


**Figure 2. Mean optical density values of affected and healthy dentin and their respective behavior at 0, 3, and 6 months.**



The values of affected regions and healthy dentin in relation to their behavior over time were statistically different (Figure 2). This finding reinforces the idea that affected and healthy dentin is part of an extremely dynamic process inside the dentin-pulp complex. An intervention in the affected dentin stimulates the complex as a whole, and has consequences not only for the affected dentin adjacent to restorations, but for all of the dentin and pulp structures.

The results of this study support the idea that the partial carious dentin removal technique (sealing the cavity with glass ionomer cement) is successful as evidenced by the increase in dentin radiopacity. This fact suggests that the dentin-pulp complex can be repaired and even stimulated to achieve a physiological process of defense and heal as a consequence. However, additional studies with longer follow-up periods and using clinical, radiographic, histological, and micro-structural analyses are necessary to provide evidence-based scientific proof.

Under the methodological conditions and according to the results of this study, it can be concluded that the radiographic optical density values of the dentin region varied over the six-month follow-up period. The most significant difference was found in the region of the affected dentin between zero and three months and suggests that the partial dentin caries removal technique significantly stimulates dentin remineralization during this period.

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