COMPARISON OF DIFFERENT METHODS OF EXCAVATION CONTROL FOR MINIMALLY INVASIVE CARIES TREATMENT

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Introduction: The change in the color of dentine, registered by visual and tactile control methods is an objective method for the assessment of demineralization of the in-depth carious process. The aim of the research is that, by means of an in vitro experiment, to study the changes in the in-depth color of dentine, during mechanical caries excavation, comparing two control methods, the visual and tactile and also by fluorescence.
Methodology: The subjects of the study were 32 extracted teeth, with dentine occlusal or proximal carious lesions similar in size (D3), excavated down to the healthy or affected dentine, controlled with two methods - visual and tactile (by Bjørndal) and fluorescent. Pictures were taken from the tooth samples and the resulting images were subject to a software color analysis with the use of the Hue, Saturation and Brightness color system.
Results: Visual and tactile controlled mechanical excavation down to the healthy dentine results in the dentine at the bottom of the excavation having the same characteristics as the healthy dentine, which indicates that the method is sufficiently objective but there is a risk of over-excavation. After applying the fluorescently controlled method and the fluorescence disappears after the excavation, the dentine at the bottom of the excavation has a much darker coloration than the healthy dentine.
Conclusion: The fluorescent method of control gives us the opportunity to leave non-infected, demineralized dentine at the bottom of the cavity and should be the preferred method in the light of minimally invasive treatment of dentinal caries.
Keywords: dentin, excavation, fluorescence, minimally invasive caries treatment.

1. Introduction

In recent years the treatment with minimal intervention has been the subject of studies in all fields of modern medicine. With regard to deep dentinal carious lesions, dental science focuses on researching and developing new methods related to the choice of technique of excavation, control during excavation and stimuli for internal remineralisation. [1,2,3,4] The goal is to prevent or detect the disease in its early stage, modern diagnostic and treatment procedures with minimal intervention for the maximum preservation of dental structures to be used. The minimally invasive excavation in the treatment of deep dentinal caries requires a controlled, selective and sparing approach. Various techniques for selective excavation only of irreversibly damaged dentine have been developed.[3,5,6,7] The concepts for step excavation have been created. Control during excavation is getting to be an important condition for a selective removal only of irreversibly damaged dentine and preservation of that which minimally infected is and that has preserved remineralizing

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Table 1. Distribution of the extracted teeth included in the experiment

Control method	Mechanical excavation	
	Up to affected dentine	Up to healthy dentine
Visual/tactile (Bjørndal)	Group 1	Group 2
Fluorescence with Facelight	Group 3	Group 4

Table 2. Criteria for evaluating dentine

Visual criteria - color of dentine	Tactile criteria [with dental probe] - dentine texture
black dark brown light brown yellow light yellow	very soft dentine - the probe penetrates easily and flakes off pieces of it; soft dentine - the probe penetrates and leaves the dentine without resistance; medium-hard dentine - slight resistance when probing; hard dentine - when driving on dentine light resistance and a white trail remains; hard non carious dentine - when probing slightly creaking and resistance.

properties (relatively preserved three-dimensional collagen structure, preserved intrafibrillar mineral). In practice the most often method applied to control the excavation is the classical - visual and tactile, assessing the color and texture of carious dentine. The method is highly subjective, and requires the development of other methods to control the excavation by staining with dyes, by stimulating of the dental structures' fluorescence etc.[1,8,9] In recent years FACE (Fluorescence Aided Caries Excavation) technology was established as an innovative method for the detection of infected dentine. It uses the principle of fluorescence, wherein a substance by light of a certain wavelength (most often in the blue or ultraviolet range, it can be also laser light) irradiated is and it absorbs the photons, which secondarily emits to a longer wavelength light. Control of excavation is based on different fluorescence of various dental tissues and on red fluorescence of bacterial products.[10] Such a device is *Facelight* light probe (W&H Dentalwerk Bürmoos GmbH, Bürmoos, Austria), where the tooth is illuminated with violet light (405 nm). Infected dentine can be seen in red and healthy structures in green color.[7] SOPROLIFE (SOPRO ACTEON Imaging, La Ciotat cedex, France) is a similar device consisting of an intraoral camera with the capability of high magnification device for detecting caries by black green fluorescence due to the loss of mineral and control excavation in dentine.[11,12] There are studies that use a diode laser fluorescence (DIAGNOdent pen, KaVo Dental GmbH, Biberach, Germany) to control the excavation of carious dentine not with standing that the apparatus itself is designed primarily for the diagnosis of initial carious lesions.[9,13] Comparative studies with regard to accuracy, sensitivity and specificity of various methods for assessment of the residual dentine have been conducted. Usually these are in vitro experiments on extracted teeth, where as a standard a histological findings, visualized by confocal microscopy, scanning electron microscopy or confocal laser scanning microscopy, etc. are evaluated.[14,15] The results give priority to the modern fluorescent techniques that objectify in best way the infected dentine and give the possibility of minimally invasive excavation in the deep dentinal caries treatment.[11,16,17]

The purpose of this study is to investigate changes in the in-depth dentine color at mechanical caries excavation using two *in vitro* control methods, the visual and tactil and the fluorescence with Facelight.

2. Material and methods

The subject of our experiment were 32 extracted teeth with similar sized dentinal occlusal or proximal carious lesions (D3), divided into 4 groups oof 8 teeth each (Table 1).

During the excavation, the samples were evaluated clinically by two methods: A visual tactile method[18] and the fluorescence method with a caries detector - Facelight (W&H Dentalwerk Bürmoos GmbH, Bürmoos, Austria) - an innovative method for detection of infected dentine, in which the tooth is illuminated with violet light up to 405 nm. Glasses with filter up to 500 nm of the optical spectrum are used. Infected dentine can be seen in red and healthy structures in green-like color.

The criteria used for dentin evaluation are presented in Table 2. We used the following criteria for healthy and affected dentine specified in our previous study.[19] Criteria for excavation up to healthy dentine (Table 2):

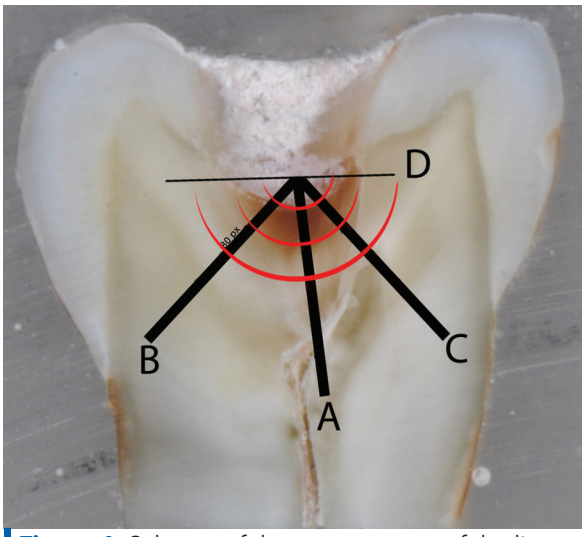

Figure 1. Scheme of the arrangement of the lines in the object of the analysis

- In the visual and tactile control method - yellow or light yellow dentine; hard consistency, slightly creaking and resistance when probing;
- In the fluorescence control method with Facelight - pale red fluorescence disappears.

Criteria for excavation up to affected dentine:

- In the visual and tactile control method - dark yellow or light brown dentine; medium-hard consistency, a slight resistance when probing with a white trail;
- In the fluorescence control method with Facelight - a weak pale red fluorescence only at the bottom of the cavity.

The cavity preparation was conducted by one examiner and the evaluations were made by 3 examiners after preliminary calibration.

2.1. Preparation of extracted teeth for the experiment

The extracted teeth used in this study were stored in a solution of distilled water with thymol. At least 24 hours prior to the excavation they were left in pure distilled water. After completion of the excavation and clinical assessments the roots were separated from the clinical crowns, then the samples were dried in alcohol solutions of increasing concentrations (30%, 70%, 90%). The cavities were isolated by restoration using temporary filling material (Adhesor, SpofaDental a.s. HQ, Jičín, Czech Republic). Then samples were packed with an epoxy resin in plastic cylinders 1.5 cm in diameter of and 3.5 cm in height. After resin polymerisation, the specimens were bisected in the axial axis of the tooth in the mesio-distal direction. Temporary restorations were removed from both halves, and then they were used for the purposes of that in vitro study about the applying of photographic equipment for dentinal changes characterisation during the excavation.

2.2. Original authors method

Developing of methods for valuation of changes in dentine during excavation, using highly specialized digital photographic equipment and software:

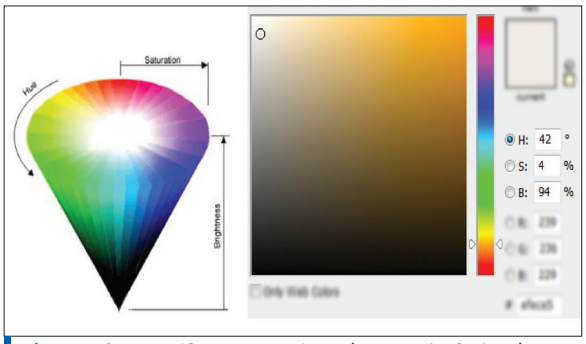

Figure 2. Hue/Saturation/Brightness (HSB) scheme

Dental samples were documentary evidenced using highly specialised digital photographic equipment consisting of the following components: body - Nikon D90, lens - Nikon AF-S Micro-Nikkor 105mm f/2.8G VR, flash - Nikon SB-R 200 Speed light Remote Kit R1 (Nikon Corp., Tokyo, Japan). Photographing the objects was carried out under the following conditions - focal distance 105 mm, coefficient of approximation - 1: 1. The resulting images underwent software analysis of the color under the developed original methodology, as follows: First we put Line D - parallel to the enamel dentine junction. Then Line A - forming an angle of 94° with the line parallel to the enamel dentine junction and intersecting the pulp chamber, Line B and Line C - bisectors of the angle between Line A and Line D, were drawn.

Three levels of depth were determined:

- Level 1 – on the surface of the excavation
- Level 2 – 80 pixels (0,4 mm) down the non excavated dentine
- Level 3 – 160 pixels (0,8 mm) down the non excavated dentine

The points where the three Lines cross the three Levels (Fig.1) were analysed with the use of specialised digital software (Adobe Photoshop CS 5.5, Adobe Systems, San Jose, CA, USA). A randomly chosen point on the area of healthy dentine was used as control point.

In each of the three points, as well as in the control point the color was measured for each parameter according to the color system - HSB (Hue, Saturation, and Brightness) (Fig. 2). HSB system is defined as a device-independent way for determining the color, i.e., once the color defined by this system; it can be reproduced isometrically by different devices. This system presents a color as a relationship of three parameters:

- **Hue** - shade of color. Practically it is the color itself. Measured in linear degrees - 0 - 360°;0° = red, 60° = yellow, 120° = green, etc.
- **Saturation** - color saturation. Measured in percentages -0%=no color, 100% =highest color intensity.
- **Brightness** - the brightness of the color. It is expressed in percentage of the black (0%) to white (100%).

Changes in the color of all points were used to

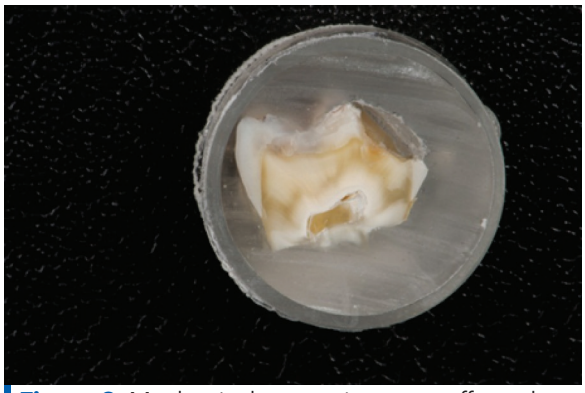

Figure 3. Mechanical excavation to an affected dentin evaluated with visual and tactile control method

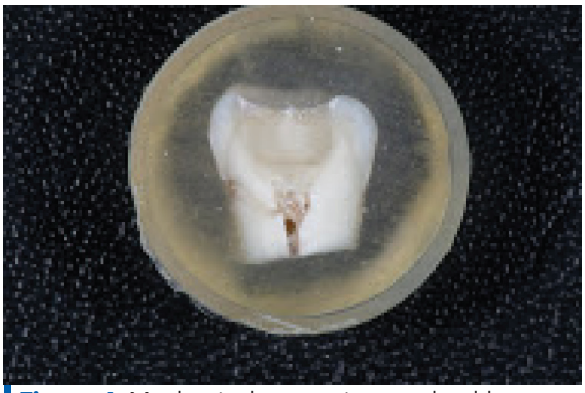

Figure 4. Mechanical excavation to a healthy dentin with visual and tactile control

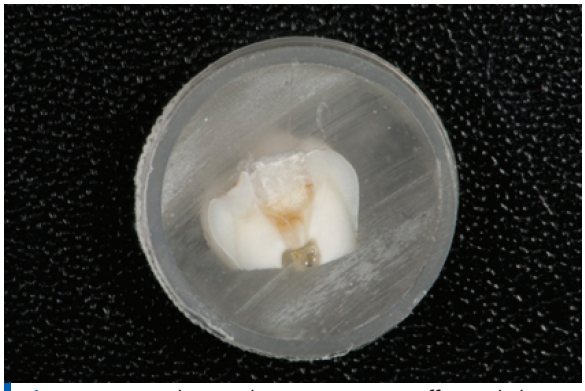

Figure 5. Mechanical excavation to affected dentin with Facelight control

Figure 6. Mechanical excavation to "non-infected" dentin with Facelight control

analyse the change of the basic parameters and comparison of the samples.

2.3. Statistical methods

The data were statistically analysed with SPSS-19 software (SPSS Inc, Chicago, IL, USA).

3. Results

3.1. Color characteristics (HSB) of healthy dentine (control point) in the four studied groups

The following table 3 presents the color characteristics of healthy dentine, which serves as control when comparing the color characteristics of the three investigated points in depth of excavated caries lesion. It is notable from the table that the color characteristics of healthy dentine in the four studied groups showed similar values for parameter H (hue) without any statistically significant differences when comparing between groups [p> 0,05]. It should be noted that the hue substantially reflects the primary color. Values between 39.00 and 41.00 are perceived by the eye close to the value of 60 (yellow color), which is considered as a characteristic of healthy dentine by Bjørndal's visual tactile scale.

The values for Saturation and Brightness complement the basic color. Saturation of the 4 surveyed groups range between 3 - 10%, which is an indicator of low intensity, typical of the lighter colors, such as yellow color and nuances of yellow, which characterizes the healthy dentine we studied.

Brightness, which is measured as a percentage from black (0%) to white (100%), in our studied samples was over 77%, which is an indicator of approaching white. Differences between groups in terms of saturation and brightness show greater variation, which is understandable due to the fact that their values are influenced mainly by the individual terms of object capturing.

3.2. Color characteristics (HSB) of dentine in the bottom of excavated cavity in depth

In the following tables characteristics of color in the center of dentine in excavated cavities (in solid or stagy dentine) in depth - 3 levels on a distance of 80 pixels (0.4 mm) or a common depth - 0.8 mm are given.

Table 4 presents the changes in the color of dentine in Group 1, after mechanical excavation to affected dentine, controlled in depth by the visual and tactile method (Fig. 3).

Table 4 shows that the surface of the remaining affected dentine at the bottom of the cavity has a color completely different when compared with the control group [shades of yellow] towards the brown shades that are darker at the surface and become brighter in depth without reaching the color of healthy dentine in depth of around 1 cm [control]. Saturation in various test points decreases from

Table 3. Color characteristics of control point in different groups

HSB Group	H (Hue) ^{0}		S (Saturation) %	B (Brightness) %
	n	Mean ± Std. Dev	Mean±Std. Dev	Mean ± Std. Dev
1 group affected with the visual and tactile method	8	40.25 ± 4.20	8.25 ± 4.74	83,88 ± 5,89
40.63± 1.768.00 ± 5.242 group healthy with the visual and tactile method 83,63 ±1,92	8	39.00 ± 5.39	3.75 ± 3.11	77,38 ± 4,66
4 group healthy with the fluorescent method 3 group affected with the fluorescent method	8	40.88 ± 4.22	6.63 ± 2.26	77,5 ± 4,11
PS T-test	$t_{1,2}$= 0.52 (p= 0.61) $t_{2,3}$= - 0.81 (p=0.43) $t_{1,3}$= - 0.20 (p= 0.82) $t_{2,4}$= - 0.77 (p= 0.45) $t_{1,4}$= - 0.30 (p= 0.77) $t_{3,4}$= - 0.15 (p= 0.88)		$t_{1,2}$= 2.25 (p=0.04) $t_{2,3}$= -1.97 (p=0.07) $t_{1,3}$= 0.10 (p=0.90) $t_{2,4}$= -2.12 (p=0.05) $t_{1,4}$= 0.87 (p=0.40) $t_{3,4}$= 0.68 (p=0.57)	$t_{1,2}$= 2.45 (p=0.02) $t_{2,3}$= 3.51 (p=0.00) $t_{1,3}$= 0.11 (p=0.91) $t_{2,4}$= 0.57 (p=0.95) $t_{1,4}$= 2.51 (p=0.03) $t_{3,4}$= 3.82 (p=0.02)

Table 4. Changes in the color of dentine in Group 1

HSB Level	H (Hue) ^{0}		S (Saturation) %	B (Brightness) %
	N	Mean ± Std. Dev	Mean ± Std. Dev	Mean ± Std. Dev
1-st level	8	32.75 ± 4.10 42.13 ± 9.70	68.63 ± 8.94	
2-nd level	8	35.58 ± 4.54	30.38 ± 1.15	73.13 ± 8.79
3-rd level	8	34.13 ± 6.58	18.50 ± 13.41	75.63 ± 8.45
Control group	8	40.25 ± 4.20	8.25 ± 4.74	83.88 ± 5.89
PS T-test	$t_{1,k}$= - 3.28 (p=0.01) $t_{1,2}$= - 1.97 (p=0.09) $t_{2,k}$= - 1.98 (p=0.08) $t_{1,3}$= - 0.71 (p=0.05) $t_{3,k}$= - 2.46 (p=0.04) $t_{2,3}$= 0.98 (p=0.36)		$t_{1,k}$= 8.65 (p=0.00) $t_{1,2}$= 2.45 (p=0.04) $t_{2,k}$= 6.27 (p=0.00) $t_{1,3}$= 4.56 (p=0.00) $t_{3,k}$= 2.79 (p=0.03) $t_{2,3}$= 3.45 (p=0.01)	$t_{1,k}$= -5.86 (p=0.00) $t_{1,2}$= -3.72(p=0.01) $t_{2,k}$= -4.88 (p=0.00) $t_{1,3}$= -5.19(p=0.00) $t_{3,k}$= -3.82 (p=0.01) $t_{2,3}$= -4.41 (p=0.00)

42.13% to 18.50% and the brightness increased from 68-63% to 75.63% (p <0.05). In comparison to healthy dentine the values of saturation and brightness did not reach the values of control (p <0.05). Table 5 presents the changes in the color of dentine in Group 2, after mechanical excavation to *healthy* dentine, controlled in depth with visual and tactile method (Fig. 4).

The colors of all studied depths are as close as possible to the control (healthy dentine) (p> 0.05). The same relationship is also seen in terms of the saturation and brightness of the obtained average values obtained of the test points in the three levels of the depth (p> 0.05). When controlling the excavation with Facelight (Fig. 5), the color of dentine is estimated as affected when a light pink fluorescence is noticed, localized only in the bottom of the cavity. The affected dentine is reliably darker than the control (healthy dentine) (p< 0.05), saturation stands out from control in the entire depth of examined dentine, and brightness authentically distinguishes authentically from control only on the surface of the dentine (Table 6). It is notable that in depth, the color of the points studied remains constant and reliable; differences in depth are not found.

We introduce the "non-infected" dentine term because the presence of fluorescence at the bottom of the cavity is due to microbial bio-products in dentinal tubules during the carious process, and the absence of fluorescence in the dentine is assumed as dentine without microorganisms, which we refer to as "non-infected dentine" (Fig. 6). It differs in color from the healthy dentine registered by the visual and tactile control, which will be shown in the following results (Table 7). When excavating to "non-infected dentine" (excavation stops when the fluorescence disappears, which is considered to be a lack of micro-organisms), the color of the surface is fairly darker than the control (healthy dentine) and lighter than the affected (Table 7). Differences in hue and saturation as compared to control are supported by statistical confidence (p< 0.05). This is different from the trend observed in group 2 (with excavation also to healthy dentine but with visual and tactile control), where the values are very close to the control (p> 0.05). The second feature that we observe in this group is that the color remains constant in depth, but becomes less intense and with higher brightness (p< 0.05).

Table 5. Changes in the colors of dentine in central point of group 2

HSB Level	H (Hue) ^{0}		S (Saturation) %	B (Brightness) %
	N n	Mean ± Std. Dev	Mean ± Std. Dev	Mean ± Std. Dev
1-st level	88	38.00 ± 5.29	10.50 ± 4.38	75.00 ± 6.70
2-nd level	88	35.50 ± 9.63	9.13 ± 4.19	75.50 ± 7.37
3-rd level	8 8	37.63 ± 5.73	8.63 ± 5.73 75.88 ± 6.20	
Control	8	39.00 ± 5.40	3.75 ± 3.11	77.38 ± 4.66
PS T-test		$t_{1,k}$=-0.42[p=0.69] $t_{1,2}$=1.13[p=0.29] $t_{2,k}$=-1.12[p=0.30] $t_{1,3}$=0.15[p=0.88] $t_{3,k}$=-1.02[p=0.34] $t_{2,3}$=-0.67[p=0.52]	$t_{1,k}$=3.35[p=0.01] $t_{1,2}$= 1.29[p=0.24] $t_{2,k}$=2.34[p=0.05] $t_{1,3}$= 0.87[p=0.42] $t_{3,k}$=2.31[p=0.05] $t_{2,3}$= 0.28 [p=0.89]	$t_{1,k}$= -1.19[p=0.27] $t_{1,2}$= -0.61[p=0.56] $t_{2,k}$=-0.95[p=0.38] $t_{1,3}$= -1.08[p=0.32] $t_{3,k}$=-1.01[p=0.35] $t_{2,3}$= -0.60 [p=0.57]

Table 6. Changes in colors of the dentine in central point of group 3 (affected with Facelight control)

HSB Level	H (Hue) ^{0}		S (Saturation) %	B (Brightness) %
	N	Mean ± Std.Dev	Mean ± Std.Dev	Mean ± Std.Dev
1-st level	8	31.00 ± 9.34	35.25 ± 17.90	70.00 ±7.54
2-nd level	8	34.25 ± 5.70	36.75 ± 22.95	71.00 ± 8.28
3-rd level	8	34.25 ± 6.78	27.13 ± 23.90	74.13 ± 5.64
Control	8	40.63 ± 1.77 8.00 ± 5.24	83.63 ± 1.92	
PS T-test		$t_{1,k}$= - 3.00(p=0.02) $t_{1,2}$= -1.38(p=0.21) $t_{2,k}$= - 3.37(p=0.01) $t_{1,3}$= -1.43 (p=0.20) $t_{3,k}$= - 2.60(p=0.03) $t_{2,3}$= -0.00 (p=1.00)	$t_{1,k}$= 3.35 (p=0.01) $t_{1,2}$= 1.29(p=0.24) $t_{2,k}$= 2.34(p=0.05) $t_{1,3}$= 0.87(p=0.42) $t_{3,k}$= 2.31(p=0.05) $t_{2,3}$= 0.28 (p=0.89)	$t_{1,k}$= -6.40(p=0.00) $t_{1,2}$= -1.21(p=0.26) $t_{2,k}$= -5.16(p=0.00) $t_{1,3}$= -1.96(p=0.09) $t_{3,k}$= -4.86(p=0.00) $t_{2,3}$= -1.59 (p=0.16)

4. Discussion

Our hypothesis was based on the studies referred in the literature,[12,22] which presented evidences that changes in the color of carious dentine were comparable to the rate of carious process progression - partial or complete carious destruction, degree of demineralization and infection of the dentine during the carious process. There is a directly proportional relationship between the color of dentine and the extent of its destruction by caries (demineralization) on the one hand and the degree of infection on the other, on the basis of which a system of visual tactile control during excavation is created.[3,16,20] On the other hand, the degree of infection of the dentine is comparable to the degree of fluorescence with Facelight detector by which we controlled the mechanical excavation.

The color of the dentine is characteristic for the level of demineralization of dental hard tissues. Our study showed that from the three parameters of color, the hue is the most stable indicator that can be used as a basis for comparative study, and saturation or brightness are complementary for color characteristic. The color of healthy dentine is close to yellow, where similar values with those of the controls are prerequisite for reliable comparative results in each group and between groups. The results indicate that the visual and tactile assessment of the excavation to healthy dentine is sufficiently precise and objective, when the purpose of the excavation is to reach a healthy dentine. This is not recommended in modern trends for minimally invasive excavation, when uncontrolled removal of dentine until reaching healthy dentine is rejected and "over excavation" is considered as harmful as insufficient excavation. There is evidence that reaching the area of healthy dentine results in a greater probability of microorganisms penetration in the depth of dentinal tubules, and further risk of dentine infection.[15, 21]

According to the results obtained in our study, we can conclude that dentine evaluated as affected by Facelight control has a degree of demineralization, which remains uniform in depth and differs significantly from healthy dentine. If we make analogy between color changes and the degree of dentine demineralization in depth, due to the advancing front of the carious process, we could

Table 7. Changes in the colors of dentine of Group 4

HSB Level	H (Hue) ^{0}		S (Saturation) %	B (Brightness) %
	N	Mean ± Std. Dev	Mean ± Std. Dev	Mean ± Std. Dev
1-st level	8	37.38 ± 3.02	23.38 ± 7.11	73.63 ±5.29
2-nd level 8	36.75 ± 3.69	15.75 ± 8.12	75.88 ± 4.36	
3-rd level	8	34.75 ± 4.74	11.38 ± 6.19	78.00 ± 3.67
Control	8	40.88 ± 4.22	6.63 ± 2.26	77.50 ± 4.11
PS T-test	$t_{1,k}$= - 1.99 (p=0.09) $t_{1,2}$= 1.17 (p=0.28) $t_{2,k}$= - 2.30 (p=0.05) $t_{1,3}$= 1.74 (p=0.13) $t_{3,k}$= - 2.87 (p=0.02) $t_{2,3}$= 1.28 (p=0.24)		$t_{1,k}$=5.99 (p=0.00) $t_{1,2}$= 3.07 (p=0.02) $t_{2,k}$= 3.06 (p=0.02) $t_{1,3}$= 2.88 (p=0.02) $t_{3,k}$= 2.38 (p=0.05) $t_{2,3}$= 1.31 (p=0.23)	$t_{1,k}$= -2.44 (p=0.05) $t_{1,2}$= -2.91 (p=0.02) $t_{2,k}$= -1.52 (p=0.17) $t_{1,3}$= -3.12 (p=0.02) $t_{3,k}$= 0.62 (p=0.55) $t_{2,3}$= -2.96 (p=0.02)

say that in fluorescence control, affected dentine remains demineralized to a greater extent in the studied depth of 1 cm. Our results show another very interesting trend that "non-infected dentine" does not necessarily have the classical yellow characteristic of healthy dentine. The non-infected dentine, obtained by fluorescence control is partially demineralized and it must be preserved without the need of "over excavation" of dentine. A similar *in vitro* study was carried out by Benarjee et al. on 12 extracted carious molars.[3, 22] Researches for micro hardness (at Knoop), emission of auto fluorescence signal [using a confocal laser scanning microscope], and digital photo images on the sliced surfaces of tooth samples in set points were conducted. The results obtained are used for direct comparisons between color, auto fluorescence and micro hardness of each lesion. The authors demonstrated that a correlation, which is not absolute, exists between the changes in the analyzed parameters. According to them, the transmission of fluorescent signal stops before reaching a dentinal layer, which micro hardness values are close to those typical for healthy dentine. This dentine layer is of a light yellow to light brown color and a relative hardness.[3,16,22] That allows researchers to propose the use of auto fluorescence signal emitted by carious lesions as an objective and reliable criteria for control during excavation.

According to the results obtained in our previous study,[19] there is a reverse-proportional relationship between the color of the dentine and the intensity of the fluorescent signal. A similar conclusion, however for a correlation between the hardness of the dentine and intensity of the fluorescence signal is observed in other studies.[11,20,22] There is also evidence for in vivo studies demonstrating the close association and relationship between the texture and color of carious dentine and quantity of microorganisms in it.[14,15]

The overall conclusion that can be drawn is that at the bottom of the excavated cavities, the remaining affected dentine differs in all 3 characteristics of the color, which is in the area of the brown tones and in depth hue changes to yellow, the saturation to low rates, which is indicative of a reduction in saturation and brightness changes in the direction of increasing the percentage (towards white). This indicates the presence of remaining demineralized dentine as the degree of demineralization decreases in depth when using the visual and tactile control and remains more uniformly demineralized when uniformly fluorescent control is used. Excavation to healthy dentine with visual and tactile-controlled method differs in color from "non-infected dentine" registered with the fluorescent control method, whose color is an indicator of a partial demineralization but with no microorganisms or microbial bio-products, which is a prerequisite for such dentine to be retained and it is preferred to over excavating to healthy dentine or reaching the underlying pulp. In the first case, the color is fairly close to the color of healthy controls, and the second is distinguished reliably from it.

5. Conclusions

Our study shows that changes in the color of dentine registered by HSB system can be used as an objective method for monitoring the degree of demineralization in depth of the carious process in *in vitro* studies.

The methods for excavation under the visual and tactile method for control provide inconsistent and non-satisfactory results: Mechanical excavation to affected dentine under the visual and tactile method for control leads to remaining of demineralized dentine up to the depth of 0.8 mm. The demineralization zone does not acquire the characteristics of healthy dentine, and cannot be defined as non-infected. In excavation to healthy dentine, the characteristics of dentine in depth match those of healthy dentine, but with high possibility of over excavation.

On the other hand, during excavation controlled by the fluorescent control method, the color characteristic of the dentine when the fluorescence signal disappears indicates the presence of partially demineralized but non-infected dentine, which can be preserved doing cavity preparation. Thus the fluorescent control allows selective and gentle excavation, which is recommended in minimally invasive treatment of dentinal caries.

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Questions

What does the fluorescent control method of excavation rely on?

❑ a. Different fluorescence of mineralized and demineralized dentine;
❑ b. Lack of fluorescence of bacterial products;
❑ c. Different fluorescence of dental tissues and bacterial products;
❑ d. Intense fluorescence of healthy dentine.

What is the main disadvantage of the visual and tactile control method of excavation?

❑ a. Dentine on the bottom of the excavation remains demineralised;;
❑ b. Risk of over-excavation;
❑ c. Excavation leaves infected dentine in the cavity;
❑ d. There are no disadvantages.

What is the color of dentine after applying the fluorescently controlled method and the fluorescence disappears?

❑ a. Much darker than the color of healthy dentine;
❑ b. The same color as that of healthy dentine;
❑ c. Lighter than the color of healthy dentine;
❑ d. Can be lighter or darker than the color of healthy dentine.

Changes in the color of dentine registered by HSB system...

❑ a. Can be used as a subjective method for monitoring the degree of demineralization in depth of the carious process;
❑ b. Do not relate with the degree of demineralization in depth of the carious process;
❑ c. Cannot be used as an objective method for monitoring the degree of demineralization in depth of the carious process;
❑ d. Can be used as an objective method for monitoring the degree of demineralization in depth of the carious process..