OPEN ACCESS

GAVIN PUBLISHERS

Dentistry: Advanced Research

Korhonen MH, et al. Dent Adv Res 4: 163.

DOI: 10.29011/2574-7347.100063

Research Article

Challenges in Digital Imaging Fiber-Optic Transillumination Method

MH Korhonen[1], L Piipari[1], N Sämpi[1], P Pesonen[2], T Joensuu[3], ML Laitala[1,4*], V Anttonen[1,4]

[1]Research Unit of Oral Health Sciences, Department of Pedodontics, Cariology and Endodontics, University of Oulu, Finland

[2]Northern Finland Birth Cohorts, Faculty of Medicine, University of Oulu, Finland

[3]Kuopio University Hospital, Kuopio, Finland

[4]Medical Research Center, University of Oulu, Oulu University Hospital, Finland

[*]**Corresponding author:** Marja-Liisa Laitala, Research Unit of Oral Health Sciences, Department of Pedodontics, Cariology and Endodontics, University of Oulu, Finland. Tel: +358406786785; Email: marja-liisa.laitala@oulu.fi

Citation: Korhonen MH, Piipari L, Sämpi N, Pesonen P, Joensuu T, et al. (2019) Challenges in Digital Imaging Fiber-Optic Transillumination Method. Dent Adv Res 4: 163. DOI: 10.29011/2574-7347.100063

Received Date: 11 October, 2019; **Accepted Date:** 28 October, 2019; **Published Date:** 01 November, 2019

Abstract

Objectives: The aim of the study was to evaluate the challenges in Digital Imaging Fiber Optic Transillumination (DIFOTI) method and to analyze the proportions and causes of possible failures in the images. We also aimed to examine the variation of the failures in scanning between the clinicians using the DIFOTI device.

Materials and Methods: Study group comprised 52 voluntary university students aged 18 to 30 years. DIFOTI images of the proximal surfaces of all premolars and molars were scanned by five trained clinicians. The types of failures in imaging were investigated for a total of 1664 proximal tooth surfaces. To investigate the inter-examiner agreement considering the image analysis, an experienced clinician and a fifth-year dental student analyzed DIFOTI images of 1024 tooth surfaces.

Results: The majority (55%) of the DIFOTI images were considered unacceptable because of technically unsuccessful (43%) or missing (11%) tooth surfaces. Underexposure (60%) and projection failures (17%) were the most common shortcomings, followed by overexposure (7%). Of the images, 12% were granular or blurry and 3% had saliva bubbles. Failure rates between the clinicians varied from 27% to 48%.

Conclusions: After a brief introduction and little experience with the technique, missing and failed tooth surfaces were common using DIFOTI. Thorough education and training in the use of DIFOTI are necessary. Analyzing DIFOTI images retrospectively is difficult if tooth surfaces cannot be identified reliably.

Clinical Relevance: DIFOTI maybe a feasible complementary tool in caries detection but training both for scanning and analyzing the DIFOTI images is essential.

Keywords: Dental Caries; Education; Fiber-Optic Technology; Transillumination

List of Abbreviations

DIFOTI	:	Digital Imaging Fiber-Optic Transillumination
VT	:	Visual-tactile
BW	:	Bitewing
FOTI	:	Fiber-Optic Transillumination
FSHS	:	Finnish Students' Health Service

Introduction

Reliable diagnostics is an essential part of controlling and managing dental caries [1]. Successful caries control requires detection of early carious lesions, which is, in addition to risk assessment, a cornerstone in the control of the caries disease. However, detecting Visual-Tactilely (VT) non-cavitated dental caries lesions is difficult, especially on proximal surfaces [1,2]. The most common method for caries detection is Visual-Tactile inspection (VT);

however, VT alone may lead to an underestimation of dental caries lesions. Together with VT, Bitewing (BW) radiography is widely used and found to be an excellent additional method for detecting interproximal caries lesions [3]. Other complementary tools to the traditional visual tactile method are laser fluorescence, Fiber-Optic Transillumination (FOTI) and Digital Imaging Fiber-Optic Transillumination (DIFOTI) [4].

Laser fluorescence is based on light intensity changes via absorption or scattering in materials associated with different stages of dental caries [2]. In another optical method based on light-induced fluorescence of tooth material, so-called quantified light-induced fluorescence or QLF, the digital images are modified and saved in a PC for analyses [5]. Combining methods leads to increased accuracy in caries diagnostics. However, new methods alone possess poor specificity and thus lead to false positive findings [6].

The DIFOTI method uses visible light for transilluminating the tooth [7]; as such, the principle of the DIFOTI technique is somewhat similar to that of FOTI. Additionally, DIFOTI technology utilizes a Charge Coupled Device (CCD) camera and computer controlled image acquisition [8]. Images can be captured and saved on a computer. Feasibility and noninvasiveness, as for radiation, are considered benefits of DIFOTI. This novel method has been indicated to have a higher sensitivity for detecting caries lesions, especially in interproximal surfaces, even compared with radiography [5]. However, acquiring images of good quality by this method is of the utmost importance and evidence on this topic is still limited.

Considering activity and depth estimation of dental caries lesions, even third-year dental students have been found to perform well in the visual detection and assessment of caries lesions [9]. When detecting dental caries lesions by laser fluorescence, the performance of dental students and experienced clinicians has been found to be similar [10]. Recently, DIFOTI was reported to detect more initial and manifested caries lesions compared with clinical visual examination and bitewing radiography [11]. Kühnisch et al. (2016) evaluated validity of transillumination for interproximal caries detection, but did not, however, study the role of the examiner or the impact of the technical quality of the images [12].

This study aimed to investigate challenges and possible failures in DIFOTI imaging. The objective was to evaluate the challenges in different tooth types and tooth surfaces including the effect of the scanning clinician. Another aim was to investigate the feasibility and acceptability of the use of the DIFOTI method by comparing the findings on failures between a fifth-year dental student and an experienced clinician, both not very familiar with the DIFOTI technique. The hypothesis was that the DIFOTI method is easy to adapt and failures are rare. It was also hypothesized that the more distant teeth and tooth surfaces possess more failures than teeth that are easily accessible while scanning the teeth. The effect of the clinician in charge of scanning was considered likely on the quality of the images.

Materials and Methods

Study population and study sample

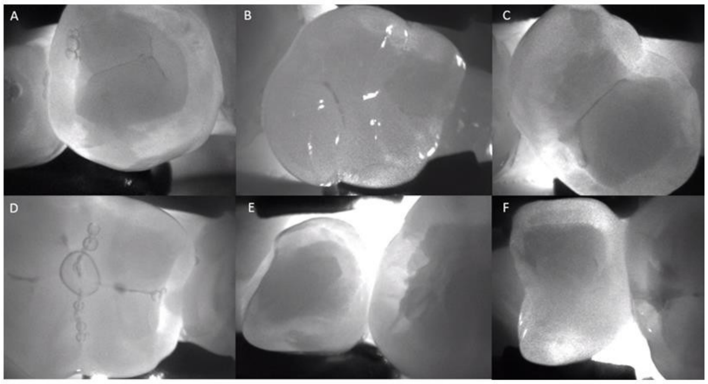
All 18 to 30-year-old university students who came for a regular dental check-up between November 2013 and February 2014 at the dental clinic of the Finnish Students' Health Service (FSHS) in Oulu, Finland, were asked to participate in the study. In total, 137 students volunteered and fulfilled the inclusion criteria (aged 18 to 30 years, not pregnant) were included. In the present study, the DIFOTI images of randomly selected 52 participants out of the entire study group were analyzed (a convenience sample).

DIFOTI

The dentists working in FSHS (n=5) carried out clinical examinations including DIFOTI scanning (DiagnoCam 2170 by KaVo, Biberbach Germany, resolution 640 K x 480 K, wavelength 780 nm). Education on the theoretical basis and the use of the DIFOTI device was provided by a KaVo representative in hands-on sessions. The clinicians were advised to scan all 1st and 2nd premolars and molars of the participants. A dental nurse from FSHS recorded the findings in a database as called out by the dentist. The PNG images were saved for later analysis using a specific program offered by the manufacturer. In case, when more than one image per tooth surface had been scanned and saved in the files, the clearest of the images was included in the analyses.

DIFOTI image failures in different teeth and tooth surfaces and the association of the number of failed and missing surfaces in DIFOTI images scanned by 5 clinical examiners at FSHS were analyzed by a fifth-year dental student (MK). For training and calibrating of the analyzer, an experienced clinician and professor (VA) gave a lecture on the topic with DIFOTI images. During training VA acted as a golden standard and images were evaluated together with MK until consensus was reached in all cases.

DIFOTI images were analyzed using a normal computer screen in a darkened room without changing the brightness or contrast of the images. The surface was considered missing when it could only be seen partly or not at all in the image. Absence of a view of the dentin enamel junction line indicated poor or not sufficient quality of the image for reliable analysis; and in such cases, the image was considered as failed. Atypically shaped shades at proximal surfaces were ignored (considered sound) if they were not at the contact point. The types of failures were classified as: blurry, granular, underexposed, overexposed, projection failure, or saliva bubbles. Examples of all failure types in the DIFOTI images are presented in Figure 1.



A: Good transillumination, enables proximal inspection

B: Underexposure of a molar

C: Overexposure of a second premolar's distal surface

D: Missing distal surface and enamel caries at the mesial surface of a lower first molar

E: Projection failure, overexposure and good transillumination in the same image

F: Granular image

Figure 1: Examples of DIFOTI images representing good (A) and poor (B-F) quality.

Inter-examiner agreement

To investigate inter-examiner agreement between the experienced clinician (VA) and the fifth-year dental student (MK) independently evaluated DIFOTI images of 61% of the participants (1024 tooth surfaces in total) several months after the scanning. For evaluating inter-examiner agreement, following variables were analyzed: failured/analyzable tooth surface, and sound tooth surface/surface needing restorative treatment.

Statistics

The data were described as frequencies and proportions. To investigate the association between the groups, cross tabulation was used. The differences between the groups (tooth types and tooth surfaces) were tested using Pearson's chi-square or Fisher's exact tests, with the value $p < 0.05$ representing statistically significant differences. To analyze the inter-examiner agreement for DIFOTI findings by a dental student and an experienced dentist, agreement proportions were calculated. For all analyses, SPSS (version 22.0, SPSS, Inc., Chicago, IL, USA) was used.

Ethical consideration

FSHS and the Regional Ethics Committee of the Northern Ostrobothnia Hospital District provided approval to conduct the study. Participation was voluntary and informed consent was obtained from all individual participants included in the study. Data were collected and analyzed without personal IDs.

Results

For image quality analysis, a total of 832 teeth were scanned, and the total number of proximal surfaces was 1664. Only about half (46%) of the scanned surfaces were acceptable for cariological analyses. The prevalence of missing surfaces was 11.4%, which was noticeably less than that of failed surfaces (42%). Most missing surfaces were found in molars, especially in the lower jaw (15%). Failed surfaces were typically found both in upper (48%) and lower molars (44%) (Table 1).

Status of proximal tooth surfaces in DIFOTI images	Upper premolars n (%)	Upper molars n (%)	Lower premolars n (%)	Lower molars n (%)	Total n (%)
Missing	39 (20.5)	52 (27.4)	35 (18.4)	64 (33.7)	190 (11.4)
Failed	170 (23.7)	200 (27.9)	165 (23.0)	182 (25.4)	717 (43.1)
Analyzable	207 (27.3)	164 (21.7)	216 (28.5)	170 (22.5)	757 (45.5)
Total	416 (25.0)	416 (25.0)	416 (25.0)	416 (25.0)	1664 (100)

Table 1: Distribution of analyzable, missing and failed tooth surfaces in premolars and molars.

The most common cause for failures was improper transillumination of the tooth involved or improper positioning of the device sensor, leading to under- or overexposed images. The most common failure type was underexposure (60% of the failed surfaces), followed by projection failures (17%) and poor quality of the images (granular 11% and blurry 1%). Images were overexposed in 7% of the cases. Saliva bubbles were less common reason for a failure (3%).

Improper transillumination was most commonly found for the 1st premolars and 2nd molars; the underexposure again was found to be more likely in molar than in premolar regions; it appeared in 2nd molars. By contrast, overexposure was the most likely type of failure in premolars, especially lower 1st premolars (34% of all teeth overexposed). Projection failures were also most common in premolar areas: 84% of all poor projections were found in premolars. Saliva bubbles appeared with similar frequency in all locations. The number of missing surfaces was the lowest in 2nd premolars and 1st molars. However, 39% of all missing surfaces were observed in 2nd molars, followed by the 1st premolars (Table 2).

Tooth group	Analyzable tooth surfaces	Cause of failure n (%)						Missing	Total number of tooth surfaces
		Blurry	Granular	Under-exposure	Over-exposure	Projection failure	Saliva bubbles		
Upper 1st premolar	92 (44.2)	0	21 (23.3)	40 (44.4)	10 (11.1)	17 (18.9)	2 (2.2)	26 (12.5)	208 (100)
Upper 2nd premolar	115 (55.3)	2 (2.5)	7 (8.8)	42 (52.5)	1 (1.3)	26 (32.5)	2 (2.5)	13 (6.3)	208 (100)
Upper 1st molar	108 (51.9)	1 (1.2)	8 (9.9)	58 (71.6)	3 (3.7)	7 (8.6)	4 (4.9)	19 (9.1)	208 (100)
Upper 2nd molar	56 (26.9)	1 (0.8)	14 (11.8)	91 (76.5)	7 (5.9)	3 (2.5)	3 (2.5)	33 (15,9)	208 (100)
Lower 1st premolar	88 (42.3)	0	6 (6.3)	33 (34.7)	17 (17.9)	39 (41.1)	0	25 (12.0)	208 (100)
Lower 2nd premolar	128 (61.5)	3 (4.3)	8 (11.4)	25 (35.7)	10 (14.3)	21 (30.0)	3 (4.3)	10 (4.8)	208 (100)
Lower 1st molar	105 (50.5)	1 (1.3)	6 (7.5)	63 (78.8)	1 (1.3)	6 (7.5)	3 (3.8)	23 (11.1)	208 (100)
Lower 2nd molar	65 (31.3)	3 (2.9)	9 (8.8)	79 (77.5)	1 (1.0)	4 (3.9)	6 (5.9)	41 (19.7)	208 (100)
Total	757 (45.5)	11 (1.4)	79 (11.0)	431 (60.1)	50 (7.0)	123 (17.2)	23 (3.2)	190 (11.4)	1664 (100)
The proportions (%) of the causes of failure calculated from the total number of failed tooth surfaces.									

Table 2: The proportions of the analyzable, missing and failed tooth surfaces and proportions of causes of failures.

The distal surfaces of the 2nd molars had the highest proportion of failed images. In the lower 2nd molars, 86.5% of images had failed, whereas the respective figure for upper 2nd molars was 81.7%. The proportions of failed mesial surfaces of the same teeth were 51.0% and 64.4%, respectively. The difference was the greatest between the mesial and distal surfaces as for missing surfaces (Table 3).

Cause of the failure n (%)										
Tooth	Surface	Analyzable n (%)	Blurry	Granular	Under exposure	Over exposure	Projection failure	Saliva bubbles	Missing n (%)	Total n (%)
1st premolar upper	**Mesial**	54 (51.9)	0	11 (10.6)	21 (20.2)	6 (5.8)	7 (6.7)	0	15 (14.4)	104 (100)
	Distal	49 (47.1)	0	10 (9.6)	19 (18.3)	4 (3.8)	10 (9.6)	1 (1.0)	11 (10.6)	104 (100)
2nd molar upper	**Mesial**	37 (35.6)	0	7 (6.7)	48 (46.2)	2 (1.9)	2 (1.9)	2 (1.9)	6 (5.8)	104 (100)
	Distal	19 (18.3)	1 (1.0)	7 (6.7)	43 (41.3)	5 (4.8)	1 (1.0)	1 (1.0)	27 (26.0)	104 (100)
1s premolar lower	**Mesial**	44 (42.3)	0	4 (3.8)	18 (17.3)	7 (6.7)	22 (21.2)	0	9 (8.7)	104 (100)
	Distal	49 (47.1)	0	2 (1.9)	15 (14.4)	10 (9.6)	17 (16.4)	0	11 (10.6)	104 (100)

ISSN: 2574-7347

2nd molar lower	**Mesial**	51 (49.0)	0	5 (4.8)	31 (29.8)	1 (1.0)	3 (2.9)	5 (4.8)	8 (7.7)	104 (100)
	Distal	14 (13.5)	3 (2.9)	4 (3.8)	48 (46.2)	0	1 (1.0)	1 (1.0)	33 (31.7)	104 (100)
Total		317 (38.1)	4 (0.5)	50 (6.0)	243 (29.2)	35 (4.2)	61 (7.6)	10 (1.2)	120 (14.4)	832 (100)

Table 3: The causes of failures of the images; first premolars and second molars, mesial and distal surfaces.

For one of the 52 participants (examinees), the ID of the clinical examiner was missing in the data. Thus, the analysis concerning differences between the examiners (Table 4) included 51 examinees. The number of examinees per examiner varied from 2 to 25. Between the examiners, proportions of failed surfaces varied from 27% to 48%. Proportions of underexposed surfaces per examinee varied between 35% and 81%, and proportions of overexposed surfaces varied between 1% and 15% (Table 4).

Clinical examiner ID	Number of examinees n (%)	Mean number of failed surfaces n (%)	Mean number of underexposed surfaces n (%)	Mean number of overexposed surfaces n (%)	Mean number of surfaces with projection failures n (%)	Mean number of missing surfaces n (%)
1	25	12.6 (39.4)	7.4 (58.7)	0.8 (6.4)	2.5 (19.8)	0.56 (1.2)
2	2	8.5 (26.6)	3.0 (35.3)	0.5 (5.9)	2.5 (29.4)	1.0 (11.8)
3	10	14.8 (46.3)	8.6 (58.1)	2.2 (14.9)	0.5 (3.4)	0.1 (0.7)
4	3	14.0 (43.4)	11.3 (80.7)	1.3 (9.3)	1.0 (7.1)	0.7 (5.0)
5	11	15.3 (47.8)	10.1 (66.0)	0.1 (0.7)	3.2 (20.9)	0.8 (5.2)
Total	51 (100)	13.5 (42.2)*	8.3 (25.9)	0.9 (2.8)	2.2 (6.9)	0.6 (1.9)*
* proportions are from the mean failed						

Table 4: Proportions of failed and missing images and most common reasons for failures (underexposure, overexposure, projection failure) for different clinical examiners.

The inter-examiner agreement between the experienced clinician and the dental student was 73.1% for intact surfaces, 64.5% for surfaces needing restorative treatment, and 18.7% for failed surfaces, respectively.

Discussion

DIFOTI provides a modern noninvasive tool for caries detection. Acquiring high quality DIFOTI images seems to be challenging for dentists with only basic training in the use of the device. According to this study, failures in DIFOTI imaging can occur during scanning, recording, but even during analysis of the images. Specifically labelling of the images is crucial, if they are analyzed only afterwards and by other dentists.

In this study, a significant proportion of the DIFOTI images of the scanned proximal tooth surfaces were not of sufficient quality for cariological analyses. Adequate transillumination requires positioning of the occlusal tip of the device parallel to the tooth axis and placement deep enough to cover the gingival margin around the tooth. Thus, poor positioning causes poor transillumination which consequently creates blurry, granular or under- or overexposed images. Achieving the correct position of the tip is difficult especially in the posterior sites of the dentition because of the lack of space. These pitfalls were demonstrated in this study by the large number of failed and missing images. Furthermore, to raise the quality and reproducibility of DIFOTI images, standardization procedures already implemented in BW-radiography [13] are needed.

Similar performance by the dental students and experienced clinicians has been shown with respect to clinical caries detection as well as with laser fluorescence scanning [10]. Here, the fifth-year dental student had limited experience as regards to analyze even radiographic images, unlike her experienced counterpart. Apparently, the fifth-year student classified a higher proportion of the DIFOTI images as failed than the senior dentists did. A confounding factor in analyzing the DIFOTI images was the fact that identifying the images afterwards was confusing as for which tooth surface and even tooth was concerned. Separated from the clinical situation, it is extremely challenging to correctly identify the tooth surfaces - and also the teeth - even if labelled by the recorder, which also had some obvious shortcomings. A proper labelling system for teeth and tooth surfaces makes analyses easier and more reliable. This is important, for instance, if oral hygienists scan and label teeth for dentists in future. Despite all these issues, the agreement concerning intact surfaces exceeded 73%, which can be considered good.

Differences in the quality of the DIFOTI images taken by different clinical examiners were obvious. Also, the number of images taken by different examiners differed greatly. More experience and practice in using DIFOTI would most likely have increased the number of successful images. Training and practice must be emphasized here.

The strength of this study is that the topic is current, and interest in DIFOTI imaging as a diagnostic tool seems to be growing. To our knowledge, there are no previous studies concerning failed or missing DIFOTI images, which also increases the value of this study because it may provide tools for avoiding pitfalls. The sample size was large enough to point out the most common failures and teeth and tooth surfaces most susceptible to failures. The images were analyzed without the possibility of changing the brightness or the contrast of the images. Software tools allowing for changes in the brightness and contrast would be required for a better analysis.

The participants in this study were young university students aged 18-30 with relatively good oral health, which minimizes confounding findings such as restorations covering the caries lesion or tooth fractures. Indeed, young people are an ideal target group for the use of DIFOTI method. Monitoring lesion progression noninvasively after caries controlling procedures, for example, is definitely a benefit of the DIFOTI method. The images of the lesion can be compared with the previous ones, which helps to decide on the need for further treatment. The method can also be helpful in motivating patients for good self-care. The technology underlying DIFOTI scanning is not based on radiographic radiation. This is why it could be preferred over bitewing radiography, e.g. for children and during pregnancy.

Based on the present results, it can be proposed that basic training on the use of the device without prior clinical experience is not enough to enable clinicians to obtain images of good quality. Thorough training for the clinical use of the device as well as for the retrospective analysis of the images seems to be necessary. In the training for the use of the DIFOTI device, correct positioning of the occlusal tip must be emphasized. This technique should be introduced to dental students and demonstrated with hands-on sessions during training for caries detection.

Conclusions

There is a need for reliable new diagnostic tools for detecting caries lesions, especially the early detection of lesions [5]. This study endeavors to point out some possible shortcomings in the use of DIFOTI, giving indications on how to avoid them. Because the reported proportion of failed and missing surfaces in DIFOTI images was considerably high, but could be avoided with training, thorough training of clinical dentists in the use of the DIFOTI method is necessary. Training for not only capturing the images, but also for labelling them correctly and analyzing them thoroughly are important. Further clinical studies on the validity of the DIFOTI method for caries detection are needed.

Acknowledgements

The authors wish to thank all the dentists and other staff at the Finnish Students' Health Service in Oulu, Finland for their valuable input and participation. For providing the device KaVo DIAGNOCam for this study, the manufacturer and KaVo Scandinavia AB are acknowledged.

Conflicts of Interest

The authors declare that they have no conflict of interest.

References

1. Baelum V (2010) What is an appropriate caries diagnosis?. Acta Odontol Scand 68: 65-79.
2. Neuhaus KW, Longbottom C, Ellwood R, Lussi A (2009) Novel lesion detection aids. Monogr Oral Sci 21: 52-62.
3. Ritter AV, Ramos MD, Astorga F, Shugars DA, Bader JD (2013) Visual-tactile versus radiographic caries detection agreement in caries-active adults. J Public Health Dent 73: 252-260.
4. Abogazalah N, Ando M (2017) Alternative methods to visual and radiographic examinations for approximal caries detection. J Oral Sci 59: 315-322.
5. Kühnisch J, Ifland S, Tranaeus S, Hickel R, Stösser L, et al. (2007) *In vivo* detection of non- cavitated caries lesions on occlusal surfaces by visual inspection and quantitative light-induced fluorescence. Acta Odontol Scand 65: 183-188.
6. Twetman S, Axelsson S, Dahlén G, Espelid I, Mejàre I, et al. (2013) Adjunct methods for caries detection: a systematic review of literature. Acta Odontol Scand 71: 388-397.
7. Stookey GK, Gonzales-Cabezas C (2001) Emerging Methods of Caries Diagnosis. J Dent Educ 65: 1001-1006.
8. Bin-Shuwaish M, Yaman P, Dennison J, Neiva G (2008) The correlation of DIFOTI to clinical and radiographic images in class II carious lesions. JADA 139: 1374-1381.
9. Parviainen H, Vähänikkilä H, Tjäderhane L, Anttonen V (2013) Teaching modern dental caries detection to third year dental students. BMC Oral Health 13: 70.
10. Bengtson A, Gomes A, Mendes F, Cichell L, Bengtson N, et al. (2005) Influence of examiner's clinical experience in detecting occlusal caries lesions in primary teeth. Pediatr Dent 27: 238-243.
11. Laitala M-L, Piipari L, Sämpi N, Korhonen M, Pesonen P, et al. (2017) Validity of Digital Imaging of Fiber-Optic Transillumination (DIFOTI) in Caries Detection on Proximal Tooth Surfaces. Int J Dent: 8289636.
12. Kühnisch J, Söchtig F, Pitchika V, Laubender R, Neuhaus KW, et al. (2016) In vivo validation of near-infrared light transillumination for interproximal dentin caries detection. Clin Oral Investig 20: 821-829.
13. Meyer-Lueckel H, Balbach A, Schikowsky C, Bitter K, Paris S (2016) Pragmatic RCT on the Efficacy of Proximal Caries Infiltration. J Dent Res 95: 531-536.