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Comparison of the Detection of Proximal Caries in Children and Youth Using DIAGNOcam[®] and Bitewing Radiovisiography

Porównanie wykrywalności próchnicy na powierzchniach międzystycznych zębów u dzieci i młodzieży po zastosowaniu urządzenia DIAGNOcam[®] i radiowizjografii skrzydłowo-zgryzowej

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Abstract

Background. Detecting early carious lesions on tooth surfaces which are hard to reach, especially proximal ones, is the most problematic part of a dental examination. Nowadays, in clinical practice, in addition to a clinical examination, the use of subsidiary methods, such as radiovisiography or laser, in detecting proximal caries is recommended. **Objectives.** A comparison of the effectiveness of detecting caries on the proximal surfaces of primary molars, permanent molars and premolars in children and youth under 18 years old using visual and tactical examination, the laser diagnostic camera DIAGNOcam[®] (KaVo) and bitewing radiovisiography.

Material and Methods. The proximal surfaces of molars and premolars in 100 children and youth under 18 years old were examined, all of whom were patients of the Department of Pediatric Dentistry at the Medical University of Warsaw. Examination of the proximal surfaces was conducted using Digora bitewing radiovisiography, a DIAGNOcam KaVo laser camera and visual and tactical examination according to the ICDAS-II classification scale. Statistical analysis was conducted using the Wilcoxon signed-rank test. Moreover, the sensitivity and specificity of the methods was evaluated.

Results. The average patient age was 10.5 ± 3.83 years. Caries were diagnosed on 122 (10.90%) proximal surfaces of the lateral teeth in the radiovisiographic examination, on 113 (10.47%) using the DIAGNOcam KaVo intraoral camera and on 98 (4.00%) in the visual and tactical examination. A lack of statistical significance for the examination of the proximal tooth surfaces using DIAGNOcam vs radiovisiography was stated. The sensitivity of the radiovisiography was 88.33 and the specificity 84.38, whereas the sensitivity of the DIAGNOcam was 80.00 and the specificity was 81.10.

Conclusions. The diagnostic methods that were used have varied in sensitivity and specificity. Examination of the proximal surfaces using the DIAGNOcam is less sensitive than radiovisiography, as well as less specific. Both methods have limitations in usage (*Dent. Med. Probl.* 2016, 53, 4, 468–475).

Key words: caries diagnostic methods, detection of proximal caries, bitewing X-rays, DIAGNOcam, DIFOTI technology.

Słowa kluczowe: metody wykrywania próchnicy, wykrywanie próchnicy na powierzchniach stycznych, zdjęcie zgryzowo-skrzydłowe, DIAGNOcam, DIFOTI.

Dental caries is one of the most common causes of tooth loss in humans [1]. The main goal of modern dentistry is to detect caries at the earliest stage of development. This makes it possible to use minimally invasive methods of treatment [2–4].

The prevalence of caries, which remains high, still necessitates the introduction of new, more efficient, more objective and at the same time non-invasive diagnostics of caries lesions [5]. The most popular method of detecting caries in everyday dentistry is the visual and tactile examination. Specificity is one of advantages, but this method is subjective and depends on the experience of the clinician. Its limitation is that it is difficult to detect caries on the proximal surfaces of the posterior teeth because of their specific location in the oral cavity [5, 6]. During the examination, the dentist should use additional diagnostic methods to support the correct diagnosis. The most common additional methods of diagnosis are traditional radiographs and radiovisiography (RVG). RVG has significantly reduced the dose of X-rays, and the image taken digitally can be stored, processed and replicated many times [7, 8].

A caries lesion on the proximal surface can be diagnosed on the basis of its characteristic radiological image – between contact points and the ridge of the gingivae. Early lesions are visible as a notch or bowl and they fold no more than half the breadth of the enamel or they are not visible. Intermediate lesions exceed at least half the breadth of the enamel and have a triangular or V-apex shape pointing in the direction of the pulp chamber. Advanced lesions cross the dentine-enamel junction, with the apex pointing to the pulp chamber. However, while analyzing X-ray images, the dentist should be mindful of cervical burn-out, overlapping, fillings which overlap carious lesions and secondary caries, which may distort the correct interpretation of the images. Bitewing radiovisiography makes it possible to diagnose upper and lower teeth of the same side simultaneously, with minimal radiation exposure to the patient. Despite the much-reduced exposure of the patient to radiation, the dentist may not obtain the

patient's consent and not get permission to carry out the study [9].

Recently, other diagnostic methods which do not expose patients to X-rays have been introduced, such as laser intraoral camera, for example the DIAGNOcam® KaVo. This method makes it possible to detect all the stages of caries on tooth proximal surfaces, within the enamel and the dentin. The device based, on Digital Fiber-Optic Transillumination Technology (DIFOTI), generates a laser beam (wavelength 780 nm and optical power 15 mW) penetrating into the tooth tissue, which makes it possible to visualize changes of the tooth hard tissues. In places other than the correct structure, the laser beam is refracted and scattered, which distinguishes carious lesions from the healthy tissue. The image is captured by the camera, and then sent to a computer where the software allows for archiving images, as well as subsequent graphic processing [10–16]. In the images obtained with the DIAGNOcam camera, anatomical tooth edges are clearly visible and the dentine-enamel junction is very well visualized. The laser penetrates into the tissue of the tooth, presenting a black and white image on the computer screen. Healthy enamel has a light gray shade, while the dentine gives a darker gray shade. Areas with changed light transmission, e.g. enamel cracks, fillings or carious lesions, are visible as darker or lighter lines and areas of various shapes, standing out from the regular structure [17]. The size and extension of the area with irregularities in the structure depends on its actual size and shape. Owing to the visibility of the dentine-enamel junction, it is easy to evaluate whether the lesion affects only the enamel or also penetrates deeper into the dentin. Pictures taken with the DIAGNOcam camera can be thoroughly analyzed by measuring the extent of the defect with a ruler, the reversal of gray scale and sizable enlargement [18].

The aim of the study was to evaluate the effectiveness of the detection of caries lesions on the proximal surfaces of molars and premolars using visual and tactile examination, the DIAGNOcam KaVo laser camera and bitewing radiological images.

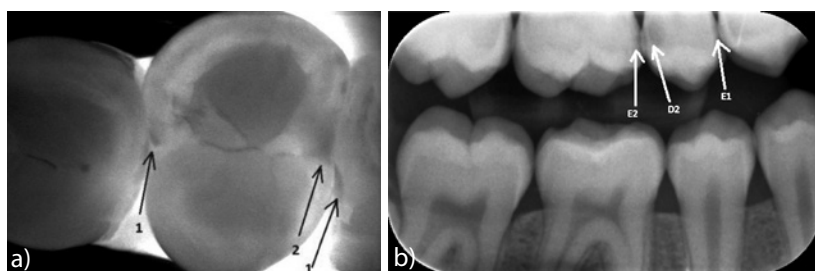


Fig. 1. a) DIAGNOcam – female patient, 14 years old. In visual and tactile examination carious lesions at tooth 16 mesially and 15 distally, code 2 according to ICDAS-II, were detected; b) RVG-scores according to Hinze et al. [20], Manji et al. [acc. 21] and Mejare et al. [22] classifications are indicated with arrows

Materials and Methods

The study was carried out in the Department of Pediatric Dentistry at the Medical University of Warsaw. Prior to examination, the consent of the Bioethics Committee of the Medical University was obtained (No. KB/91/2015, dated 05.15.2015). The study was conducted from August 2015 to February 2016. The study involved children aged 3 to 18 years, cooperating during each of the parts of the examination. Children who did not cooperate in each of the parts of the examination were excluded from the study, even if they did not cooperate in only one part of the examination and the rest were performed. Children whose parents did not give their written consent to the examination were also excluded. Each time, a written consent to conduct the examination was obtained from the parents or legal guardians of each patient. During the visit, each patient underwent a visual and tactile examination for caries and additional examination with the DIAGNOcam intraoral camera and bitewing RVG. Each patient was examined by two independent examiners (after previous calibration).

The visual and tactile examination was conducted inside the dental clinic under artificial lighting using a dental unit lamp with a dental mirror, periodontological probe and air spray to dry the tooth, after its cleaning, and rated according to the International Caries Detection and Assessment System (ICDAS-II) [19]:

- 0 – sound,
- 1 – first visual change in enamel,
- 2 – distinct visual change in enamel,
- 3 – localized enamel breakdown,
- 4 – underlying dentine shadow,
- 5 – distinct cavity with visible dentine,
- 6 – extensive cavity within visible dentine.

Examination with DIAGNOcam intraoral camera was performed with the dental unit lamp off, on dried, previously cleaned surfaces of the teeth. The tip of the device embraced the lingual/palatal and buccal tooth surface. After setting, the best angle image was saved in the patient's virtual chart. The image obtained from the camera was evaluated according to the Hinze et al. [20] classification:

- 0 – light transmission unchanged,
- 1 – shadow visible in the enamel,
- 2 – shadow visible in the dentin.

The next stage of the study was the examination of the proximal surfaces of posterior teeth with bitewing radiovisiography according to the classifications by Mejäre et al. [22] and Manji et al. [acc. 21].

Mejäre et al. [22] classification:

- 0 – no visible radiolucency,
- 1 – radiolucency in the enamel,

- 2 – radiolucency in the enamel up to the enamel-dentin junction,

- 3 – radiolucency with a broken enamel-dentin junction but with no obvious progression in the dentin,

- 4 – radiolucency with obvious spread in the outer half of the dentin,

- 5 – radiolucency in the inner half of the dentin.

Manji et al. [acc. 21] classification:

- 0 – no changes,

- E1 – radiolucency involving less than ½ outer part of the enamel,

- E2 – radiolucency involving more than ½ inner part of the enamel,

- D1 – radiolucency involving less than ⅓ outer part of the dentine,

- D2 – radiolucency exceeding less than ⅓ inner part of the dentine,

- D3 – radiolucency involving more than ⅓ inner part of the dentine.

Statistical analysis including sensitivity and specificity of the methods was conducted using the Wilcoxon signed-rank test where the statistically significant difference was $p < 0.05$.

Results

The research group enrolled 136 people, but finally the study involved 100 patients, ranging in age from 3 to 18 years, including 48 boys and 52 girls. The average patient age was 10.5 ± 3.83 years. Twenty-two children or their parents didn't agree to participate in the study, and 14 were excluded due to the lack of cooperation during the examination. The compatibility between the researchers was stated as 73.4% using Cohen's kappa coefficient.

The number of teeth and surfaces examined using the visual and tactile examination, DIAGNOcam KaVo laser intraoral diagnostic camera and bitewing radiovisiography is stated in Table 1.

In the visual and tactile examination, carious lesions were detected on 9 (4%) proximal surfaces of molars and premolars, on 113 (10.47%) surfaces in the examination with the DIAGNOcam intraoral camera, and with bitewing radiovisiography on 122 (10.9%) proximal surfaces. Out of the 100 children who were examined, in 30 there were no changes detected with the visual and tactile examination but they were detected using one of the other examination methods. A lack of statistical significance ($p < 0.05$) in this range was observed only for the examination with RVG for class D2 and D3 according to the Manji et al. [acc. 21] clas-

Table 1. Number of teeth and proximal surfaces examined with visual and tactile examination, DIAGNOcam KaVo laser intraoral camera and bitewing radiovisiography

Tooth examined		Method of examination					
		visual and tactile examination		DIAGNOcam		RVG	
		teeth n	surfaces n	teeth n	surfaces n	teeth n	surfaces n
Permanent molars	maxilla	250	500	107	214	114	228
	mandible	251	502	107	214	117	234
Permanent premolars	maxilla	187	374	79	158	78	156
	mandible	170	340	76	152	78	156
Primary molars	maxilla	180	360	83	168	85	170
	mandible	184	368	88	176	87	174
Total		1222	2444	540	1080	559	1118

Table 2. Number of teeth and proximal surfaces with caries detected on proximal surfaces using visual and tactile examination, DIAGNOcam KaVo laser camera and bitewing radiovisiography

Teeth examined		Method of examination											
		visual and tactile examination				DIAGNOcam				RVG			
		teeth		surfaces		teeth		surfaces		teeth		surfaces	
		n	%	n	%	n	%	n	%	n	%	n	%
Permanent molars	maxilla	7	0.57	10	0.98	19	3.52	19	1.76	12	2.15	12	1.02
	mandible	4	0.33	7	0.29	10	1.85	12	1.11	10	1.79	12	1.02
Permanent premolars	maxilla	11	0.9	12	0.49	15	2.78	15	1.39	10	1.79	13	1.1
	mandible	8	0.65	8	0.33	11	2.04	12	1.11	12	2.15	13	1.1
Total number of permanent teeth and proximal surfaces		30	2.45	37	1.51	55	10.19	52	4.81	44	7.87	50	4.24
Primary molars	maxilla	34	2.78	34	1.39	28	5.19	33	3.06	38	6.8	41	3.47
	mandible	27	2.21	27	1.1	18	3.33	22	2.04	27	4.83	31	2.63
Total number of primary teeth and proximal surfaces		61	4.69	61	4.0	46	8.52	55	5.09	65	11.6	72	6.1
Total number of teeth and proximal surfaces		91	7.45	98	4.0	101	18.7	113	10.46	109	19.5	122	10.31

sification as well as for class 4 and 5 in the Mejare et al. [22] classification. The reference value was ICDAS-II score 0.

The number of teeth and surfaces with carious lesions on proximal surfaces detected in the visual and tactile examination, DIAGNOcam and bitewing radiovisiography is stated in Table 2.

The comparison of the visual and tactile examination, examination with DIAGNOcam intraoral camera and bitewing radiovisiography, including the classifications used, is stated in Table 3. In the examination using the DIAGNOcam intraoral camera, the most frequent score was code 2 according to the Hinze et al. [20] classification, the least frequent was code 1. On the other hand, with radiovisiography, the most frequent scores were D2 and D3 according to the Manji et al. [acc. 21] classification and 4 and 5 according to the Mejare

et al. [22] classification. The least frequent was code E2 in the Manji et al. [acc. 21] classification and code 2 in the Mejare et al. [22] classification.

The sensitivity, specificity and confidence intervals of the methods used are stated in Table 4. A statistically significant difference was obtained only for the examination with visual and tactile examination vs RVG ($p = 0.028$). Diagnosis with DIAGNOcam vs RVG did not show statistically significant differences.

The images obtained from the DIAGNOcam KaVo confirm the presence of carious lesions on the proximal surfaces of teeth 16 and 15, scored with the Hinze et al. [20] classification, respectively 1 and 2. This indicates a deeper stage of the carious process in tooth 15, which was confirmed with the RVG image in which the lesion scored D2 according to the Manji et al. [acc. 21] classification. In ad-

Table 3. Comparison of visual and tactile examination, examination with DIAGNOcam KaVo laser camera and bitewing radiovisiography

Visual and tactile examination					DIAGNOcam					RVG									
ICDAS II Scale	teeth		surfaces		Hinze et al. scale	teeth		surfaces		Majare et al. scale	teeth		surfaces		Manji et al. scale	teeth		surfaces	
	n	%	n	%		n	%	n	%		n	%	n	%		n	%	n	%
1	1	1.1	1	1.02	1	50	49.5	53	46.9	1	19	17.43	21	17.2	E1	19	17.43	21	17.2
2	23	25.87	23	23.5	2	51	50.5	60	53.1	2	32	29.36	34	27.87	E2	32	29.36	34	27.87
3	21	23.08	22	22.45						3	20	18.35	23	18.85	D1	20	18.35	23	18.85
4	13	14.29	17	17.35						4	17	15.6	21	17.21	D2	17	15.6	21	17.21
5	15	16.48	16	16.33						5	21	19.27	23	18.85	D3	21	19.27	23	18.85
6	18	19.87	19	19.39															

Table 4. Sensitivity, specificity and confidence intervals (CI) of diagnostic methods in reference to the visual method

Diagnostic method	Sensitivity %	Confidence intervals 95% CI %	Specificity %	Confidence intervals 95% CI %
RVG	88.33	45.80–77.27	84.38	79.41–100.00
DIAGNOcam	80.00	40.89–72.96	81.10	69.77–99.84

dition, both the diagnosis with DIAGNOcam and with RVG revealed decay on the mesial surface of tooth 16, as well as on the mesial surface of tooth 15. Both lesions were not visible in the visual and tactile examination and they were evaluated as code 1 in the Hinze et al. [20] classification and as code E2 and E1 in the Manji et al. [acc. 21] classification.

Discussion

The clinical examination is the most important element for the correct diagnosis of caries. Other methods, such as examination with an intraoral camera or X-ray images, are the most common methods for an extended diagnosis of dentistry. Using only visual and tactile examination, one can overlook many carious lesions on the proximal surfaces, especially at an early stage. The aim of this study was to compare the effectiveness of the detection of caries with a DIAGNOcam intraoral camera and bitewing radiovisiography. It was also important to determine whether the DIAGNOcam KaVo laser intraoral camera, which uses transillumination, as a non-invasive diagnostic method, can reduce the need for radiological images, reducing the patient's exposure to X-rays. The diagnostic methods that were used in the examination have varied in sensitivity and specificity, and each of them also has limitations in its usage, and is dependent on many different factors. The experience of the clinician conducting the visual and tactile examination plays an important role, as well as adequate lighting and thorough

drying of the surface being examined, affecting the correct evaluation of tooth. The conditions in the patient's mouth also significantly affect the results obtained with the DIAGNOcam KaVo intraoral camera. The key point is a thorough cleaning of the patient's teeth before the test and thorough drying of the surface, as even a small amount of saliva prevents proper evaluation and interpretation of the tooth surface. Moreover, the presence of tartar deposits, a large number of stains, or amount of plaque, or fillings can distort the image transmitted by the DIAGNOcam camera, which presents false positive results.

Currently, there are few publications about the DIAGNOcam camera. In a study conducted by Paruzel-Pliskowska et al. [14], an examination with a DIAGNOcam camera was conducted on a group of 67 patients. Studies had shown greater effectiveness in detecting carious lesions using DIAGNOcam than with an orthopantomogram (OPG). The DIAGNOcam made possible the detection of 8.39% of teeth with carious lesions whereas the analysis using OPG made it possible to detect 5.59% of carious teeth, where 1966 teeth were examined [14]. In our study, the effectiveness of detecting interproximal caries with the DIAGNOcam was slightly lower (10.5%) than with bitewing radiovisiography (10.9%). In a study conducted by Strzelecka et al. [11], 80 patients were examined, aged from 19 to 26 years, under orthodontic treatment or qualified for such a treatment. A total number of 1197 permanent teeth were examined (including 586 premolars and 611 molars). There were 74.40% of carious lesions diagnosed at

varied stages. 9.94% of lesions had not exceeded the outer half of the enamel, lesions which had not exceeded the dentine-enamel junction made up 30.82% of the total and lesions which had penetrated deeper into tooth tissues accounted for 33.67% [11]. Comparing these results to those obtained in our study, using the DIAGNOcam intraoral camera, we detected 46.9% of lesions which had not reached the dentine-enamel junction and 53.1% of lesions which had exceeded this junction. Using radiovisiography, 45.2% of lesions had not exceeded the dentine-enamel junction and 55% had exceeded this junction. In a study conducted by Lietz-Kijak et al. [23] on a group of 101 patients aged 19–26 years, the effectiveness of detecting primary caries, secondary caries and enamel cracks on the proximal surfaces of molars and premolars was proved. Our study has also confirmed the usefulness of detecting primary caries with the DIAGNOcam, but still the effectiveness of detecting carious lesions remains lower than with radiovisiography.

A similar study was conducted by Mirska-Miętek [2] with a group of 100 patients aged 20–30 years, using visual and tactile examination, intraoral camera, transillumination and bitewing radiovisiography. The study involved the examination of 3190 proximal surfaces of premolars and molars. The presence of caries was detected in 98% of proximal surfaces of premolars and molars. Using radiovisiography, carious lesions limited to enamel (E) were detected in 74.3% of the examined surfaces, whereas lesions reaching the dentine were in 11.5% of the surfaces. Using transillumination, 35.80% of lesions in enamel and 7.6% of lesions in dentine were detected, respectively. With visual and tactile examination, 29% of lesions limited to the enamel and 7.8% of lesions limited to the dentine were detected, respectively. In her conclusion, Mirska-Miętek [2] pointed to the radiological method as the most advantageous in the detection of early and potentially reversible carious lesions limited to the enamel surface. The diagnostic method indicated made it possible to detect twice as many carious lesions compared to the other methods [2]. The results obtained in that study were also confirmed in our study, but the difference in the detection of dental caries between the two methods was not as significant.

Higher detection of carious lesions in radiological examination was also stated in a study conducted by Pitts [24]. The author noted that radiological examination makes it possible to detect 90% of carious lesions on proximal surfaces, and a clinical examination is not sufficient as the only diagnostic method [24]. A study by Peers et al. [25] conducted *in vitro* showed the presence of statis-

tically significant differences between the sensitivity of X-ray (0.59), transillumination (0.67) and visual and tactile examination (0.38). Vaarkamp et al. [26], on the basis of their 14-year research, stated that there is higher sensitivity in the radiological examination ($1.0 - 0.71 \pm 0.01$) in the detection of caries lesions compared to the sensitivity of the transillumination method (between 0.70 ± 0.01 and 0.50 ± 0.02). This was also confirmed in our study.

Astvaldsdóttir et al. [27] conducted an *in vitro* examination of 112 proximal surfaces of premolars. As a result of examinations carried out by 8 independent examiners, they stated that the DIFOTI method showed significantly better sensitivity than other methods (RTG and RVG), but similar specificity. It seems that using DIFOTI there is an ability to determine lesions in the earlier stages of development, without extortionating the number of healthy surfaces mistakenly identified as having early carious lesions. However, during the evaluation of caries lesions which had reached the dentin, the differences in efficacy between DIFOTI and radiography were less noticeable. The differences in sensitivity are irrelevant, but both the RTG and RVG showed better specificity than DIFOTI, which means that the number of lesions mistakenly identified as decayed dentin was higher in DIFOTI than in radiography. The authors believe that the efficiency of the DIFOTI diagnostic method is higher for the diagnosis of early caries lesions and comparable to analog and digital radiography in the case of changes ongoing in the dentin [27].

The study conducted shows that there is a need for using additional diagnostic methods in the assessment of tooth health. Visual and tactile examination on its own is burdened with a high risk of failure dependent mainly on the experience of the examiner. From the cited study [14] it is evident that the evaluation of the proximal surfaces of lateral teeth is difficult because of overlapping, especially in cases of a crowding of teeth. Bitewing radiovisiography is the most accurate for the examination of proximal surfaces of lateral teeth. In case of doubt, it is recommended to use more than one diagnostic method.

According to the principles of minimal intervention dentistry, the decision of the method of treatment cannot be based only on an assessment of clinical changes, regardless of the method of examination. First of all, it must be considered for each patient individually, taking into consideration the conditions prevailing in his or her oral cavity, the activity of the caries lesion and the condition of the remaining teeth and the presence of other sources of infection.

Conclusions

The methods of examination used in this study have varied in sensitivity and specificity. The examination of the proximal surfaces of lateral teeth using a DIAGNOcam is less sensitive than with radiovisiography, as well as less specific. Each of the methods also has limitations in use.

The Hinze et al. [20] classification scale of the DIAGNOcam has narrow values and consequently becomes less detailed in deciding whether the caries involves the enamel or dentin and does not make it possible to evaluate the extent of the lesion precisely.

A clinical examination supported by radiovisiography is sufficient for proper diagnosis of caries on the proximal surfaces of teeth. DIAGNOcam KaVo laser intraoral camera is an innovative solution however it cannot be a non-invasive alternative to radiovisiography.

The examination of proximal surfaces with the DIAGNOcam diagnostic camera can play a significant role in motivating and educating the patient about oral health. It can also be used in case of precautions or lack of consent of the children's parents or legal guardians for radiological examination.

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