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POSSIBILITIES OF MODERN X-RAY EXAMINATION METHODS FOR DIAGNOSTICS OF HIDDEN DENTAL CARIES OF APPROXIMAL LOCALIZATION

Iryna I. Sokolova[1], Svitlana I. German[1], Tetiana V. Tomilina[1], Yuliia O. Slynko[1], Anatoliy M. Potapchuk[2], Karyna V. Skydan[1], Nataliia M. Udovychenko[1]

[1] KHARKIV NATIONAL MEDICAL UNIVERSITY, KHARKIV, UKRAINE
[2] UZHHOROD NATIONAL UNIVERSITY, UZHHOROD, UKRAINE

ABSTRACT

Introduction: In case of hidden carious cavities development on the approximal teeth surfaces, the clinical diagnostics of this process is difficult. Then, the diagnostics of carious lesion is not possible without carrying out X-ray examination.

The aim of the study was a comparative analysis of the effectiveness of clinical and X-ray diagnostics for hidden caries of approximal teeth surfaces.

Materials and methods: Condition of 2 963 teeth of 115 people aged from 19 to 55 was analysed. Additionally, a digital panoramic 2D diagnostics (Planmeca ProSensor, Finland) and Cone Beam Computed Tomography 3D Diagnostics (Morita, Japan) were used for clinical examination of patients.

Results: In both variants of diagnostics, the number of caries defects in the upper jaw was higher than in the lower one, and the frequency of caries lesion of various teeth groups had the following sequence in descending order: molar teeth, premolar teeth, incisor teeth and canine teeth. Hidden carious cavities of average depth and deep were detected with almost the same frequency in both variants of the study, which by 1.9 - 2.0 times respectively exceeded the frequency of superficial carious cavities detection ($p = 0.0001$). According to the results of clinical studies, hidden superficial carious cavities occurred in single cases and X-ray examination improved their diagnostics by 9.6 times ($p = 0.0000$).

Conclusions: X-ray examination allows increasing the effectiveness of diagnostics of hidden carious cavities of approximal localization by 1.2 times on the whole ($p < 0,05$). In such cases orthopantomography (OPG) has reasonably sufficient diagnostic capabilities. Definitely, 3D Cone Beam Computed Tomography (CBCT) has much more diagnostic capabilities, but its use can not be justified for the diagnostics of caries only.

KEY WORDS: dental caries, hidden cavities, approximal localization, OPG, CBCT

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INTRODUCTION

Nowadays dental caries remains the most widespread dental disease in the world, and dentists devote most of their time to its treatment. In many cases, cariosity diagnostics does not cause difficulties – caries lesion is easily recognized clinically, and, as a rule, there is no need for X-ray examination. But with caries localization on approximal surfaces, especially with teeth overcrowding, root cement caries in the subgingival area, in deep figures with a narrow inlet, in cases of suspicion of secondary caries under dental fillings or crowns, X-ray examination is crucial for diagnostics and generation of treatment planning [1, 2].

Previously, X-ray method of examination was considered additional in dentistry, in particular, in treatment of uncomplicated caries it was almost not used. But over time, due to visualization technologies progress, X-ray method of examination gradually gained a proper place among the basic diagnostic methods [3, 4, 5]. Firstly, the final diagnosis is made in view of X-ray data in the great majority of cases; secondly, no dental intervention can be considered relevant without detailed X-ray monitoring; thirdly, follow-up visits and dispensary observation of the patient should be based on regular X-ray control [5, 6, 7, 8, 9, 10].

The most up-to-date method for unbiased findings acquisition until 2007 was orthopantomography (OPG). This type of X-ray examination is widely used in dentistry today as well, but with the advent of 3D technology in radiology (Cone Beam Computed Tomography, CBCT) OPG is predominantly prescribed for the primary diagnostics [11, 12, 13].

It is known that a certain projection distortion of the object by magnitude or configuration occurs in the process of carrying out two-dimensional X-ray examination, which includes OPG [5]. It is believed that only CBCT carrying out offers the opportunity to accurately measure the distance in a straight line or a curve from one point to another, to determine the measure of the angle between the lines or areas. The object is scanned without projection

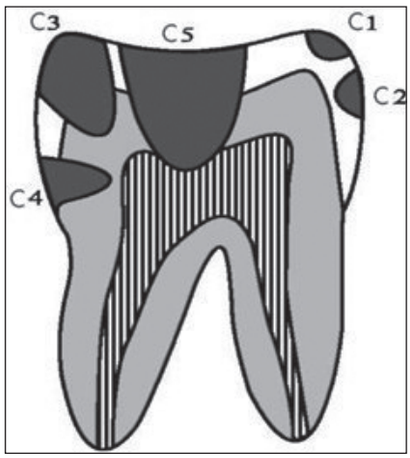

Fig. 1. X-ray classification of carious defect depth according to J. Espelid, B. Tveit (1986): C_1 – dental cavity located only within half the width of enamel; C_2 – caries that damages more than half the thickness of enamel but does not reach amelodentinal junction; C_3 – caries of enamel and dentine, in which defect takes at least half the layer of hard tooth tissues to the tooth cavity; C_4 - defect that takes more than half the thickness of dentine but is not connected to the tooth cavity; C_5 – carious defect that can reach tooth cavity.

distortion and without loss of data, practically «one to one» [2, 6, 14, 15].

Spin-Neto and co-writers (2013) [16] were interested in the problem of artifacts when the patient moved, which lead to images blurring and, consequently, to their unsuitability for diagnostic purposes. The movements of patients include breathing, heartbeats, muscle contraction and tremor. When this happens, the image becomes blurred, which is manifested in striped or annular artifacts as well as double contours. The movement of the patient leads to geometrical errors in the reconstruction process, which in turn causes poor image quality in the final format.

The authors also emphasized that the effective radiation dose for intraoral images varies from 1 to 8 microsieverts (μSv), while the effective dose when using CBCT will be higher.

Young and co-writers (2009) [17] carried out similar studies in vitro, also using 3D Accuitomo® (Morita, Japan) and compared it with solid-state sensor from Gendex® (US) in relation to caries detection. Researchers found interproximal lesions in dentine particularly with the help of CBCT images. As for interproximal enamel lesions, both CBCT and solid-state sensor showed the worst diagnostic results. But CBCT, according to the authors, more often leads to false-positive conclusions in case of caries on occlusal surfaces of teeth. It was also noted that the probability of false-positive results increased since the dentine zones display was occasionally less radiopaque. It is obvious that this false radiolucency can be caused by the geometry of irradiation, since the attenuation degree of X-rays in the dentine under the enamel tubercles is less than in the dentine of any other part of coronal part of teeth.

This effect could be avoided if it were not for separate teeth examination. An effective radiation dose of 20 μSv, which patients undergo when passing 40x40 mm CBCT scanning with Accuitomo® (Morita, Japan) is significantly differerent in comparison with four X-ray images of dental occlusion with a rectandular collimator (5 μSv).

Computer tomographic scanners are not the same, there are many modifications and not each type of a device can be effectively, and most importantly - justifiably and safely used in dentistry. Thus, in a study of a skull the patient receives 1000-1500 μSv (microsieverts) on a sequental conventional tomographic scanner, at least 400 μSv – on a spiral one and only 45-60 μSv with CBCT. We consider this advantage to be extremely important, as during X-ray studies a patient should not receive radiation exposure exceeding 1 Sv per year [7, 18].

Despite high quality of the image, the use of CBCT in dentistry has some disadvantages. Metal fillings, dental protheses, that are often in mouths of patients, cause scattered artifacts that interfere with anatomical structures identification. However, they are leveled off in the process of information processing with the artifact elimination program [3].

Tissue section on a fifth-generation dental computer tomographic scanner Vereviewepocs 3D R100 (Morita, Japan), that is used to carry out CBCT of maxillofacial area at one of the clinical bases of the Department of Dentistry of Kharkiv National Medical University, is 0.125 mm for the study of a small segment (4x4 cm) and 0.160 mm for jaws in general, which allows to diagnose minor defects.

Thus, the data accumulation regarding comparison of possible diagnostic consideration of various modern methods of X-ray diagnostics of cariosity, especially hidden caries, remains relevant today.

THE AIM

The aim of the study was carrying out a comparative analysis of clinical and X-ray diagnostics with hidden dental caries of approximal surfaces.

MATERIALS AND METHODS

115 people (68 females and 47 males at the age from 19 to 55) were involved in the study. Dental health of 2963 teeth was analyzed. The diagnostics of caries of hard tooth tissues was based on the clinical classification according to lesion depth (caries in the stain stage, superficial, medium and deep caries) and on X-Ray classification according to J. Espelid, B. Tveit (1986) (Fig. 1). Periodontal probe Explorer was used for an in-depth clinical examination, and the following equipment was used for X-ray examination: an innovative fifth-generation dental computer tomographic scanner Vereviewepocs 3D R100 (Morita, Japan) - for digital panoramic 2D diagnostics (OPG) and Cone Beam Computed Tomography (CBCT) in 3D mode; an intraoral sensor of a new standard Planmeca ProSensor (Finland) -

Table I. The number of clinically detected hidden carious cavities, depending on teeth group, localization and lesion depth, (abs., %)

Localization of carious defects, teeth group, lesion depth	The number of carious defects	
	n	%
Approximal surfaces of molar teeth	**188**	**50.81**
upper jaw:	102	54.25
of these superficial	2	
medium	45	
deep	55	
lower jaw:	86	45.75
of these superficial	-	
medium	47	
deep	39	
Approximal surfaces of premolar teeth	**119**	**32.16**
upper jaw:	61	51.26
of these superficial	-	
medium	24	
deep	37	
lower jaw:	58	48.74
of these superficial	-	
medium	21	
deep	37	
Approximal surfaces of canine teeth	**11**	**2.97**
upper jaw:	10	90.9
of these superficial	-	
medium	2	
deep	8	
lower jaw:	1	9.09
of these superficial	-	
medium	-	
deep	1	
Approximal surfaces of incisor teeth	**52**	**14.05**
upper jaw:	44	84.62
of these superficial	7	
medium	25	
deep	12	
lower jaw:	8	15.38
of these superficial	-	
medium	5	
deep	3	
Total	370	12.48

for local 2D diagnostics of several teeth in radiovisiography mode.

Caries diagnostics was carried out under the conditions of clinical encounter of patients based at University Dental Center of Kharkiv National Medical University. Certification for X-ray study carrying out normally occurred after dental examination. However, in some cases CBCT images made for other purposes such as in-depth diagnostics of endodontal pathology, periodontal diseases, sinus pathology, when planning dental implantation, etc. were evaluated first, and then clinical evaluation of teeth condition of these patients was performed.

The study conducted in accordance with the 7th revision of the principles of the Declaration of Helsinki (2013), the European Convention on Human Rights and Biomedicine.

Statistical processing of the actual material was carried out using a statistical package Statistica 13.2 with Fisher's z test and chi-square test.

RESULTS AND DISCUSSION

According to the results of the analysis of hard tissues condition of 2963 teeth, we clinically diagnosed 370 hidden carious lesions of approximal teeth surfaces, which was 12.48 ± 1.2% of cases (Table I). Carrying out X-ray examination allowed us to additionally detect 78 more hidden carious cavities of the specified localization (2.63 ± 0.2%) (Table II) and increase the effectiveness of their diagnostics by 1.2 times ($p<0,05$).

That is, the combination of both diagnostic methods allowed us to diagnose only 448 hidden caries cavities, which was 15.11 ± 1.7% of total teeth number, the condition of which was analyzed (Table II).

Table II. The number of X-ray detected hidden carious cavities depending on teeth group, localization and lesion depth, (abs., %)

Localization of carious defects, teeth group, lesion depth	The number of carious defects		The level of significance in comparison with clinically detected carious defects
	n	%	
Approximal surfaces of molar teeth	**243**	**54.25**	**0.5362**
upper jaw:	131	53.91	0.9515
of these C1	7		
C2	25		
C3	54		
C4	42		
C5	3		
lower jaw:	112	46.09	0.9620
of these C1	6		
C2	16		
C3	49		
C4	36		
C5	5		
Approximal surfaces of premolar teeth	**136**	**30.36**	**0.7569**
upper jaw:	73	53.68	0.7800
of these C1	5		
C2	8		
C3	23		
C4	36		
C5	1		
lower jaw:	63	46.32	0.7900
of these C1	1		
C2	4		
C3	21		
C4	37		
C5	-		
Approximal surfaces of canine teeth	**11**	**2.45**	**0.7838**
upper jaw:	10	90.91	0.9994
of these C1			
C2	1		
C3	2		
C4	7		
C5	-		
lower jaw:	1	9.09	-
of these C1	-		
C2	-		
C3	-		
C4	1		
C5	-		
Approximal surfaces of incisor teeth	**58**	**12.95**	**0.8660**
upper jaw:	48	82.76	0.8096
of these C1	3		
C2	8		
C3	25		
C4	12		
C5	-		
lower jaw:	10	17.24	0.9157
of these C1	-		
C2	2		
C3	5		
C4	3		
C5	-		
Total	448	15.11	0.2777

Fig. 2. Orthopantomography (OPG) of a patient D. Hidden carious cavities in teeth 1.5 (K3), 3.8 (K1), 3.7.(K1, K2), 3.6 (K2), 4.6 (K2)

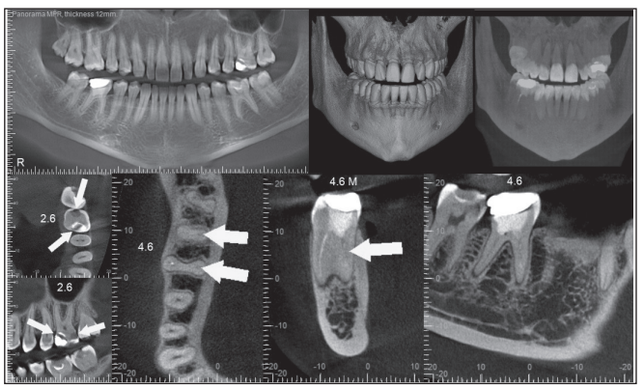

Fig. 3. OPG and CBCT screenshots of a patient P. Hidden carious cavities in teeth 2.6 (K4), 4.7 (K5)

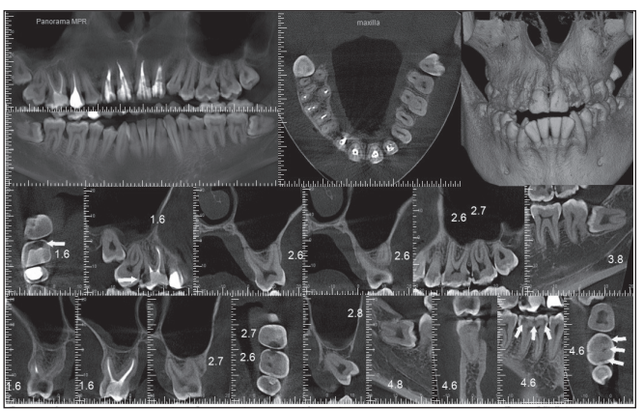

Fig. 4. OPG and CBCT screenshots of a patient H. Hidden carious cavities in teeth 2.6 (K3), 2.7 (K4), 4.6 (K2, K3), 4.8 (K1)

The data in the tables show that the frequency of hidden carious cavities detection was different depending on teeth group. It should also be noted that this dependence persisted both in clinical diagnostics and X-ray study. Thus, the number of hidden carious cavities was the highest in molar teeth (50.81% in the clinical study and 54.25% - in X-ray study, p = 0.5362). Among premolar teeth the number of hidden cavities was somewhat lower – 32.16% and 30.36% respectively, p = 0.7569. In the frontal group of teeth hidden cavities were recorded in even smaller number: among incisor teeth in 14.05% and 12.95% of cases respectively (p = 0.8660) and among canine teeth – in 2.97% and 2.45% of cases respectively (p=0,7838). That is, the frequency of caries lesion of different teeth groups had the following sequence in descending order: molar teeth, premolar teeth, incisor teeth and canine teeth, which coincides with the data of Mykhalchenko A.V. and co-writers [19].

Regarding the detection of hidden carious cavities depending on the jaws, the number of caries defects in the upper jaw was higher than in the lower jaw in both variants of the study. With that, the difference in the number of hidden cavities in upper and lower jaws was statistically significant only in frontal teeth group: in clinical study – p = 0.0001 among canine teeth and p = 0.0000 among incisor teeth; in X-ray study – p = 0.0000 among canine teeth and incisor teeth.

The characteristics of hidden carious defects according to the lesion depth was the following. Signs of carious process on approximal surfaces only within the enamel were detected clinically in 9 teeth (0.30 ± 0.1%), and using X-ray according to the criteria C1 and C2 - in 86 teeth (2.90 ± 0.1%), that is 9.6 times more (p=0,0000). The occurrence of carious cavities of medium depth was diagnosed in 169 teeth (5.70 ± 0.2%) using the clinical method and - in 179 teeth (6.04 ± 0.2%) using X-ray (according to the criterion C3). Deep carious cavities were detected clinically in 192 teeth (6.47 ± 0.3%) and using X-ray (according to the criteria C4 and C5) - in 183 teeth (6.17 ± 0.1%). That is, hidden carious cavities of medium depth as well as deep cavities were detected with almost the same frequency in both variants of the study, which by 1.9 - 2.0 times respectively exceeded the frequency of superficial carious cavities detection (p = 0.0001). Taking into account the results of clinical studies presented in Table I, superficial carious cavities are detected in single cases or are not detected at all. X-ray examination helps to improve the diagnostics of caries at early stages of its development (C1 and C2), which is confirmed by the data in Table II.

Some errors were made during the analysis of the obtained data of X-ray examination (OPG), the total number of which was 24 cases. Given that, the bulk of errors (22 observations, 91.7 ± 5.6%) was accounted for overdiagnosis. False picture of carious lesions in 22 teeth was due to dental fillings of X-ray transparent materials that do not have a geometrically correct shape and are placed without cavity liners. Overdiagnosis in remaining observations (2 cases, 8.3 ± 0.6%) is associated with the location of carious cavities below the contour height. The crucial part in clarifying the truth was to carry out in-depth X-ray examination - CBCT.

Examples of detecting hidden carious defects on OPG and in CBCT screenshots are presented in Fig. 2 - 4.

It should be noted that, in our opinion, X-ray examination was virtually irrelevant for effective diagnostics on the condition of high-quality images.

However, comparison of X-ray data with the results of clinical examination showed that distortion of carious defects sizes occurred quite often. The degree of distortions was the smallest on CBCT and OPG. The risk of false in-

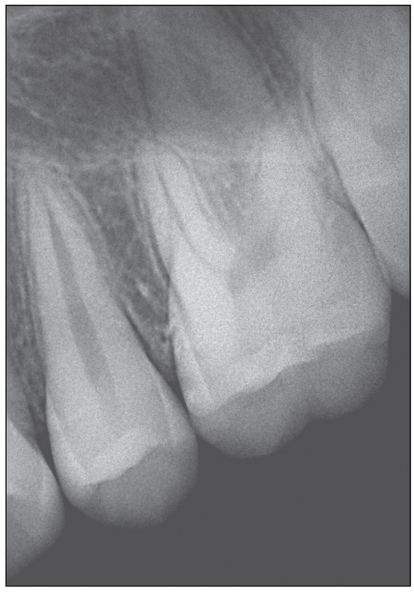

Fig. 5. Local 2D diagnostics of teeth 2.5, 2.6 in radiovisiography mode. Hidden carious cavity in a tooth 2.6 (K1)

formation was higher when carrying out OPG compared with CBCT. The reason for this in the area of incisor teeth was overlapping of the shadow from the tongue and in the area of canine teeth and premolar teeth - overlapping of approximal surfaces of adjacent teeth. The best diagnostic capabilities were in incisor teeth and molar teeth.

While carrying out CBCT, especially on the latest-generation devices, the risk of improper visualization of hidden cariosity was virtually absent and possible only in the presence of anomalies in dentition.

According to the results of the study, X-ray diagnostics of hidden caries defects among all the teeth groups was the most complicated in upper premolar teeth due to the peculiarities of the shape of these teeth and the degree of their shadows overlapping.

In case of suspicion of hidden carious cavity after carried out clinical examination, it is generally enough to refer the patient to a local 2D diagnostic procedure of several teeth in radiovisiography mode (Fig. 5).

In our opinion, it is necessary to extend the readings to X-ray examination for dental caries. The preference is to be given to orthopantomography, taking into account reasonably sufficient diagnostic capabilities of this method. Orthopantomography should be carried out strictly in the position of central occlusion in order to avoid dental tissues overlapping. In complicated cases it is rational to carry out 3D X-ray diagnostics, which allows obtaining more accurate image not only in sagital (like orthopantomography), but also in transversal and axial projections. But the use of CBCT can not be justified for the diagnostics of caries only, which coincides with the opinion of Young and others (2009), Wenzel and others (2013). The latter may, however, be an occasional finding during CBCT on condition of necessity for diagnostics of endodontal pathology, periodontal diseases in order to plan a dental implantation etc.

CONCLUSIONS

Methods of 2D diagnostics – OPG and radiovisiography have reasonably sufficient diagnostic capabilities. 3D diagnostics should never be used for caries diagnostics only. But, undoubtedly, only CBCT provides an optimal diagnostic capability to evaluate not only the topography of hidden carious cavities, but their sizes as well. Therefore, carrying out 3D diagnostics may be recommended for in-depth study of a specific clinical situation.

It would be appropriate to consider the study of frequency of secondary caries occurrence with the use of modern X-ray methods as perspectives of further researches.

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Authors' contributions:
According to the order of the Authorship.

Conflict of interest:
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CORRESPONDING AUTHOR
Iryna I. Sokolova
Kharkiv National Medical University
Kharkiv, Ukraine
tel: +380503433988
e-mail: sokdentirina@gmail.com

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