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Are there hidden caries or is this another limitation of the diagnostic conventional exams?

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Abstract

Objective: To verify the existence of hidden caries and compare the diagnosis agreement among different Examiners between the visual and radiographic exam and computed microtomography images of incipient dental lesions on the occlusal surface of extracted molars.

Methods: Two hundred and fifteen healthy teeth were extracted from the corpses of children with a mean age of 12 years and analysed by visual examination. However, only 11 teeth were included in current study because they showed suggestive caries image when examined by microtomography (micro CT scan). Occlusal sites were examined both visually and by dental radiograph by 3 different dental practitioners and results were compared and validated independently by each Examiner with computed microtomography, henceforth a gold-standard in current investigation. The coefficient of agreement was calculated by Cohen's kappa test.

Results: the coefficient of agreement among Examiners for the diagnosis by standard microtomography was excellent (K = 0.924) and moderate for both the visual (K=0.515) and the radiographic (K=0.583) examinations. Computed microtomography-produced images allowed the Examiners to visualize radiolucent areas, unseen in previous radiographic images and visual exams, in which there existed communication between enamel and/or dentine and the external environment.

Conclusion: Hidden caries was the product of the conventional exam´s limitations, or rather, the lesion was due to enamel non-collapse. Consequently, conventional exams were not accurate enough to detect the lesions.

Key words: Computed microtomography; Dental diagnostics; Incipient lesions; Dental caries

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Existem cáries ocultas ou é outra limitação para o diagnostico de exames convencionais?

Resumo

Objetivo: Verificar a existência de cáries ocultas e comparar o índice de concordância de diagnostico entres diferentes examinadores e entre o exame visual e radiográfico às imagens de microtomografia computadorizada de lesões incipientes na superfícies oclusal de molares extraídos.

Métodos: Duzentos e quinze dentes sadios foram extraídos de cadáveres de crianças com idade média de 12 anos e analisados visualmente. Entretanto, apenas 11 dentes foram incluídos no presente estudo pois apresentavam imagem sugestiva de cárie quando examinados em microtomografia (micro CT scan). Os sítios oclusais foram examinados tanto visualmente como radiograficamente por 3 cirurgiões dentistas e foram comparados e validados independentemente para cada examinador com microtomografia computadorizada, doravante um padrão ouro em pesquisa. O coeficiente de concordância foi calculados pelo teste de Cohen's kappa.

Resultados: O coeficiente de concordância entre examinadores para o diagnóstico pelo padrão da microtomografia foi excelente (K=0.924) e moderado para ambos exames visual (K=0.515) e radiográfico (K=0.583). As imagens produzidas por microtomografia permitiu aos examinadores visualizarem áreas radiolúcidas, não observadas em imagens radiográficas prévias e exame visual, no qual havia comunicação entre esmalte e/ou dentina e o ambiente externo.

Conclusão: Cárie oculta foi o produto da limitação de exames convencionais, ou melhor, a lesão se dava no esmalte não colapsado. Consequentemente, exames convencionais não foram precisos o suficiente para detecção de lesões.

Palavras-chave: Microtomografia computadorizada; Diagnóstico dental; Lesões incipientes; Cárie dental

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Introduction

Since the 1970 the pattern and prevalence of dental caries in permanent teeth have revealed a marked change [1-5]. This fact indicates that occlusal caries beneath pits and fissures, as well as clinically undetected occlusal caries beneath pits and fissures actually represent about 50% of total caries in many world communities [6]. Although several labels for this type of lesion have been forwarded, namely, 'fluoride syndrome', 'fluoride bomb' and 'hidden caries' [7-13], its aetiology is still undetermined.

Dentists who routinely examine clinically caries-free children may be shocked to discover a large caries lesion on a radiograph that they may have missed in the visual exam [7-12]. The detection rate of such lesions depends upon the prevalence of caries in the population and on the frequency of bite-wing radiographic examinations. Information on the prevalence of these lesions in world population is still lacking, even though the available data show that it ranges from 0.8% in Scotland [10] to 50% in Germany [6].

The visual examination is the method of choice to diagnose dental caries. However, clinically undetected occlusal caries are of difficult diagnosis [14] and routinely require additional exams, such as conventional radiographs [16,17] for a more accurate one [15]. However, the above technique´s limitation results from overlapping images of the occlusal surface due to a two-dimension diagnosis [18].

While the x-ray method projects the image on two planes, the CT-scan image reproduces the internal structures on three spatial planes. Thus, the structural relations are shown in depth, including the images of the segments and layers´ internal structures, particularly the mineralized tissues, with excellent definition, which favour the division of three dimensional irregularities [19,20].

Thus, the aim this study was verify the existence of hidden caries and compare the diagnosis agreement among different Examiners between the visual and radiographic exam and computed microtomography images of incipient dental lesions on the occlusal surface of extracted molars.

Methods

In current in vitro descriptive study, 215 permanent molars were collected from donated corpses of 12-15-year-old adolescents at the Forensic Medicine Institute of Pernambuco, Brazil. However, only 11 (5.11%) of the 215 teeth were included in the study because the former exhibited suggestive caries images under microtomography examination (micro CT scan). Prevalence at 5.11% was consistent with study by Maltz et al. [21].

The investigation was developed according to recommendations by the Committee in Ethics in Human Research of the University of Pernambuco, Brazil. Furthermore, parents or legal representatives agreed on the donation of the teeth and signed the informed consent. The molars in this study were clinically healthy.

Detection of caries without communication with the external environment

Due to their three-dimensional nature, CT scanning images were used as standard to detect the existence of lesions in dentine without any external communication. The teeth were then examined by three independent Examiners who looked at the images and identified the absence (0) or presence (1) of the lesions.

Accuracy of diagnosis tests

Specimens were prepared by carefully cleaning the teeth with hand scale and rotating bristle brushes with water/pumice to remove deposits of calculus, plaque or debris. They were then stored in individually identified bottles with 10.0% formaldehyde solution.

The teeth were examined by three independent Examiners employing clinical (visual), radiographic and microtomographic methods.

The three Examiners were identified as Examiner 1, Examiner 2 and Examiner 3.

Visual examination (VE)

Visual examination was performed from a dental light unit. Three independent dentists, averaging 10 years clinical experience each, examined each tooth, looked at the occlusal surfaces and identified the absence (0) or presence (1) of lesions.

Radiographic examination (RE)

In the radiographic exam, the teeth were held with utility wax and radiographed with periapical film (Ektaspeed/Eastman Kodak Company®, Rochester, USA). The focus-film distance was 20 cm, with an exposure time of 0.5 seconds. Radiographs were taken using Gnatus X-ray equipment (10 mA and 70 kV) and the films were processed in a portable dark-box and in solutions (developer and fixer) for conventional Kodak Dental X-rays (Kodak®, São José dos Campos SP Brazil), at a temperature of 24°C, for three minutes. Defective radiographs were discarded and new radiographs taken.

The radiographs were scanned and X-ray images were evaluated and graded according to criteria by Souza-Zaroni et al. [16]:

0 – No radiolucency (sound);
1 – Radiolucency in enamel;
2 – Radiolucency in enamel and dentine;
3 – Radiolucency in dentine;
4 – Radiolucency and possible pulpal involvement.

Computed microtomographic examination (MCTSE)

Teeth were imaged by micro-CT scan on a Siemens Inveon PET-CT (Siemens Molecular Imaging, Munich, Germany) for microtomographic exam. The x-ray source was set to voltage and current of 80 kVp and 500 uA, respectively. The x-ray source and CCD detector camera

were positioned to each tooth so that the effective pixel size would be 41.80 um isotropically. As many as 360 projections were retrieved for a 330-min exposure time. All projection data were reconstructed with Filtered Backprojection. The images were interpolated bilinearly, and filtered with a Shepp-Logan filter for higher resolution. Finally, conversion to DICOM format allowed the images to be viewed by DICOM medical imaging viewers.

The computed microtomography images were evaluated by the independent Examiners and graded according to criteria by Souza-Zaroni et al. [16]:
0 – No radiolucency (sound);
1 – Radiolucency in enamel;
2 – Radiolucency in enamel and dentine;
3 – Radiolucency in dentine;
4 – Radiolucency and possible pulpal involvement.

Statistical analysis

Owing to its superior image quality over the other two methods [3,19,20], the Micro-CT was chosen as the gold-standard method to compare the accuracy of the micro-CT scan with the visual and radiographic examination of the occlusal lesions.

Moreover, the inter-Examiners agreement for the tested methods (visual, radiographic and micro-CT scan) for occlusal lesion detection was also calculated and thus Cohen´s kappa statistic test expressed the coefficient of agreement for the three Examiners [22]. The kappa statistic test, formulated by Cohen in 1960, is an agreement coefficient that corrects the error due to chance by paired analysis. It compares the observed proportion of agreement between the observed (Po) and the proportion of agreement expected by chance. Rates vary between -1.0 (complete disagreement) to +1.0 (complete agreement); zero represents the agreement expected by chance [23].

Results

Since all lesion caries had a sort of communication with the external environment, Cohen´s kappa index among the three Examiners was 1, and thus excellent agreement.

Table 1 shows the results of the examination by the three Examiners employing the visual, radiographic and micro-CT scan methods and the inter-Examiner agreement for occlusal lesion detection calculated by Cohen's kappa rates. Kappa rates were 0.515, 0.583 and 0.924 for the inter-observer agreement, respectively for visual, radiographic and microtomographic examinations (Table 1).

Table 2 also shows results of the examination performed by the three Examiners employing the three methods for each tooth.

Table 3 presents the coincidence between visual examination and micro-CT scan examination, and between the radiographic examination and micro-CT scan examination for three Examiners. So that visual inspection and examination by micro-CT scan could be compared, the coincidence for the presence or the absence of communication from the external to the lesion for both techniques was taken into account.

Table 1. Cross-tables showing the relationship between the different methods and Cohen's kappa values for Inter-observer for occlusal lesion detection.

	Examiners			Total	Kappa IE
	1	2	3		
Visual					
(0) absence	7	6	6	19	
(1) presence	4	5	5	14	0.515
Total	11	11	11	33	
Radiography					
(0) No radiolucency (sound)	3	3	4	10	
(1) Radiolucency in enamel	1	1	0	2	
(2) Radiolucency in enamel and dentine	2	2	2	6	0.583
(3) Radiolucency in dentine	5	4	5	14	
(4) Radiolucency and possible pulpal involvement	0	1	0	1	
Total	11	11	11	33	
MicroCTscan					
(0) No radiolucency (sound)	1	1	1	3	
(1) Radiolucency in enamel	2	2	2	6	
(2) Radiolucency in enamel and dentine	7	7	7	21	0.924
(3) Radiolucency in dentine	0	0	0	0	
(4) Radiolucency and possible pulpal involvement	1	1	1	3	
Total	11	11	11	33	

Table 2. Tabulation of diagnoses score made by three examiners on visual, radiographic and micro-CT scan examinations for each tooth.

Examiner 1											
Teeth											
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
VE	0	0	1	0	1	0	0	0	1	0	1
RE	3	2	2	3	0	3	3	3	0	1	0
MCTE	2	1	2	2	2	2	2	1	2	1	4
Examiner 2											
Teeth											
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
VE	0	1	1	0	1	1	0	0	1	0	0
RE	3	2	2	1	3	3	0	3	0	0	4
MCTE	2	1	2	2	2	2	2	1	2	0	4
Examiner 3											
Teeth											
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
VE	0	0	1	1	1	1	0	0	1	0	0
RE	3	2	2	0	3	3	3	3	0	0	0
MCTE	2	1	2	2	2	2	2	1	2	0	4

Table 3. Coincidence between visual examination and radiographic examination in relation to micro-CT scan examination for three Examiners.

	Concordances		Total
	Yes	No	
Visual X Micro CT Scam			
Examiner A	3	8	11
Examiner B	6	5	11
Examiner C	6	5	11
Total	16	17	33
Radiography X Micro CT Scam			
Examiner A	2	9	11
Examiner B	3	8	11
Examiner C	2	9	11
Total	6	27	33

Figure 1 (a,b,c) shows a new sequence of analyzed images of tooth F. In this case, the Examiners disagreed on visual examination and agreed on the radiographic and micro-CT examinations. One Examiner stated that the clinical examination indicated a sound surface and the radiographic image was described as radiolucency in dentine, to which all Examiners agreed (Figures 1a and 1b, respectively). The micro-CT image revealed radiolucency in enamel and dentine, to which all the three Examiners agreed (Figure 2c).

Tooth E may be seen in Figure 2 (a,b,c). The three Examiners agreed that there was a lesion in the occlusal surface when examined visually (Figure 2a). However, they failed to agree on the radiographic diagnosis (Figure 2b). All Examiners detected the presence of radiolucency in enamel and dentine with micro-CT scan (Figure 2c).

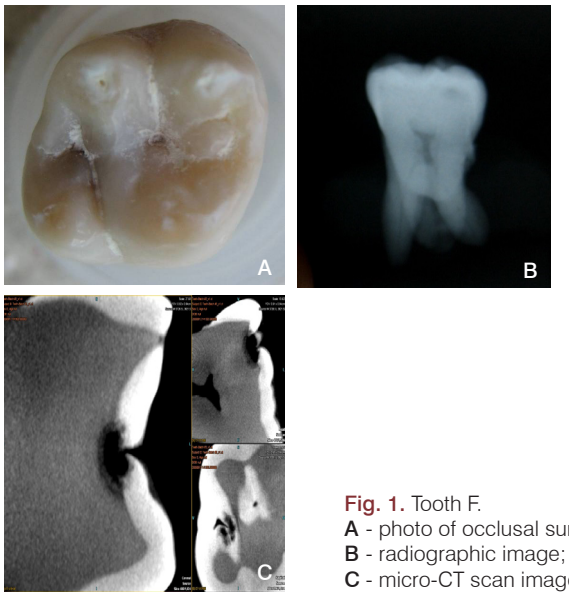

Fig. 1. Tooth F.
A - photo of occlusal surface;
B - radiographic image;
C - micro-CT scan image.

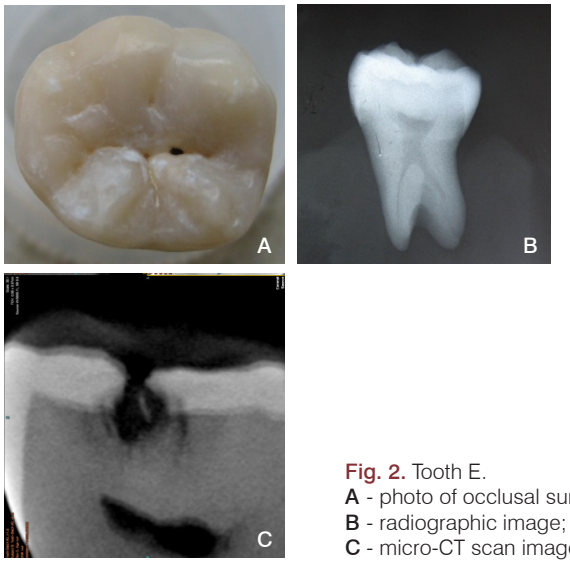

Fig. 2. Tooth E.
A - photo of occlusal surface;
B - radiographic image;
C - micro-CT scan image.

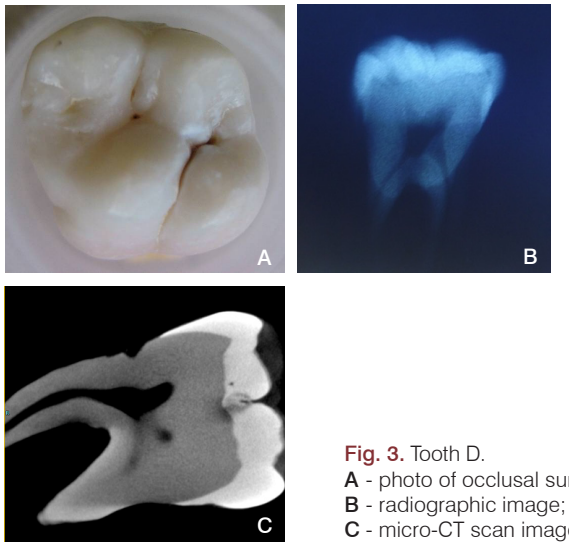

Fig. 3. Tooth D.
A - photo of occlusal surface;
B - radiographic image;
C - micro-CT scan image.

With regard to tooth D, shown in Figure 3 (a,b,c), the Examiners differed on the visual and radiographic examinations (Figure 3a and 3b, respectively). However, when the micro-CT scan examination was employed, the three Examiners were able to identify radiolucency in enamel and dentine.

Discussion

In current research, occlusal lesions were determined by three methods of caries detection that enabled dental practitioners to decide on treatment options, of which two are used routinely in dental practice whilst the third method, micro CT scan image, was chosen as the gold standard owing to its superior quality and accuracy. Results indicated that the visual and radiographic method exhibited only moderate correlation to micro CT scan (Table 1 and 3). The images observed by micro CT scan revealed that the 11 teeth examined in current research showed communication between the external environment and the occlusal lesion. Communication with the external environment detected by micro CT scan invalidated the theory that described these injuries as hidden caries [6,7,14,17,24,25,26], since, by definition, this condition would definitely show dentine lesion under non-cavitated enamel. Interestingly enough, micro CT scan showed broken enamel with dentine exposed to mouth environment. The low sensitivity and specificity of the conventional radiographs for the detection of lesions in the occlusal surface may be due to the nature of the two-dimensional, albeit low-quality, images [27].

When caries reached the dentin at the dentin-enamel junction, decay quickly spread laterally. Decay within the dentin followed a triangular pattern that pointed towards the tooth's pulp. In fact, decay pattern is typically described as two triangles (one triangle in enamel and the other in dentin) with their bases joined to each other at the dentin-enamel junction (DEJ). Actually such base-to-base pattern is typical of pit and fissure caries [28]. It should be emphasized that the radiograph-generated image failed to provide a clear view of this characteristic of occlusal caries, but clearly seen on the micro-CT scan image.

Clinical diagnosis of occlusal caries is one of the most difficult issues in the field of dentistry, with uncertainties as to its outcome. Mouth mirror, good reflected light and a blunt or a sharp probe are the dentist´s principal diagnostic tools but they lack overall accuracy in terms of sensitivity and specificity [27]. This difficulty has also been observed in current study on the diagnosis of the eleven examined teeth. For instance, when Examiners diagnosed tooth F (Figure 1), they could only partially agree on the visual examination, whereas they totally agreed on the radiographic and micro-CT scan examination (Table 2). In fact, Examiner 1 described the occlusal surface as sound, but Examiners 2 and 3 identified lesion on the same surface (Figure 1a). While the three Examiners identified radiolucency in enamel and dentine by micro-CT scan (Figure 1c), the radiographic examination only allowed the diagnosis of radiolucency in dentine (Figure 1b). It should be underscored that dental X-rays mostly failed when displaying enamel lesions and communication with the external environment. They were, however, very clear in images produced by micro CT scan (Table 3).

Limitations in radiographic diagnosis were also reported in the evaluation of some of the teeth, as may be demonstrated in the case of tooth E (Figure 2 a,b,c). The three Examiners totally agreed with regard to the visual and micro-CT scan examination for tooth E, but only partially in the radiographic examination (Table 2). Although the three Examiners were able to clinically identify lesion on the occlusal surface (Figure 2a), the dental radiographs were not helpful to show to Examiner 1 the radiolucency suggestive of lesion. Contrastingly, the Examiners 2 and 3 identified radiolucency in dentine (Figure 2b) but micro-CT scan images failed to confirm any diagnosis by the radiographic exam (Table 3). In fact, it showed the presence of radiolucency in enamel and dentine (Figure 2c) and reflected the communication of the lesion with the external environment and thus confirmed only the findings of the visual diagnosis. Examination of tooth E confirmed the limitations of the dental radiographs previously mentioned and stressed by current research. The above also indicated the importance of accurate clinical examination [29] confirmed by agreement between clinical and micro-CT scan examinations for this tooth.

Visual and radiographic examinations were not accurate enough for inter-Examiner agreement in the case of some teeth (Table 1). The diagnosis of tooth D is highly relevant to illustrate this fact (Figure 3a,b,c). The Examiners agreed only partially on visual examination for tooth D (Table 2), even though for the radiographic image the Examiners indicated total disagreement (Table 2). However, for the micro-CT scan, all Examiners produced complete agreement (Table 2). Examiners 1 and 2 identified the occlusal surface as sound by visual examination, whereas Examiner 3 identified a lesion in the area (Figure 3a). The micro-CT scan image, current research´s gold standard, showed radiolucency in enamel and dentine, as identified by the three Examiners (Figure 3c), whereas the radiographic examination (Figure 3b) revealed inter-observer confusion. While Examiner 1 identified radiolucency in dentine, Examiner 2 diagnosed radiolucency in enamel and Examiner 3 even diagnosed the tooth as not radiolucent. This boiled down to the fact that none of the diagnoses coincided with the micro-CT diagnosis (Table 1). In other words, this observation reflected the difficulties of clinical examination and also showed the limitations of dental radiographs when compared to micro-CT scan images. In this context, the incipient caries lesions were not easily visualized by dental radiograph because the visibility of caries was determined by the ratio of enamel to caries through which x-rays penetrate. Radiographic diagnosis of caries must always be supplemented with a careful clinical examination [30].

Visual examination, routinely used for detecting caries in dental clinics, has also been used in recent studies [16, 29]. In current research, the occlusal surfaces were

graded according to each Examiner´s clinical experience to demonstrate the lack of consensus diagnosis among the different dentists. This hypothesis became clear when the inter-Examiner Kappa rate (K=0.515) was employed (Table 1). It actually established only moderated agreement [23] and became a reflection of the difficulty mentioned in several studies to perform more accurate clinical caries diagnoses on occlusal surface [14]. Further, the observers hailed from different training and routine, and thus with different degrees of experience in detecting caries. Low inter-observer agreement could be related to these factors and variation in caries detection among dentists is a common phenomenon [29]. There is no guarantee that the Examiners will agree on diagnoses, since their decisions are based on previously acquired knowledge and experience [22]. Since Examiners´ experience obviously influences the diagnostic, it is important to highlight that the comparison of results involves subjective aspects, such as knowledge and clinical experience [16].

The reported specificity of visual examination for detecting occlusal lesion was described as high by various authors. Although in current research, all the teeth were considered sound by visual examination, CT scan images showed radiolucency without any doubt (Table 2). This fact also indicated that the various theories labelling this type of lesion as 'fluoride syndrome', 'fluoride bomb' and 'hidden caries' [7-13] may be nothing more than a misdiagnosis for incipient occlusal caries merely relying on visual and dental radiographic examination. Moderate inter-Examiner agreement in current investigation occurred for radiographic examination (K=0.583) (Table 1). Since the examinations were performed by the above-mentioned technique, the diagnoses with an identified lesion only on dentin were predominant (Tables 1 and 2). Consequently, the lesion which extended from the enamel, as displayed by micro-computed tomography examination, was not perceived.

On the other hand, micro-CT scan identified lesions in dentin and enamel on occlusal surfaces more clearly than the traditional radiographic survey. This might be perceived when inter-Examiners kappa rates (K=0.924) were provided (Table 1), as the images in current paper comparatively showed. However, we do not recommend micro-CT scan for dental uses due to the large amount of ionizing radiation emitted by this exam. This in vitro study aimed to verify the limitations of conventional tests for the detection of incipient caries.

Conclusion

Hidden caries is the product of conventional exam´s limitations, due to non-collapse of enamel. In addition, conventional exams are not accurate in detecting the above lesions.

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