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ORIGINAL ARTICLE

Additional information of bitewings to first time clinical examination of caries and restoration status in permanent dentition

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ABSTRACT

Objectives: Identifying additional information obtained by X-rays combined with clinical examination concerning primary caries, caries adjacent to restorations and quality of restorations.

Material and methods: A total of 240 adult patients, equally distributed in gender and six age-groups, were randomly selected from an original study population of 4,402 subjects (DANHES). Clinical and radiographical registrations on occlusal and approximal surfaces in posterior teeth were categorized into unrestored surfaces (sound/primary caries) and restored surfaces (without/with caries adjacent to restorations). Material and quality of restorations were also recorded. Chi-square and Fisher-exact tests were used for statistical analyses.

Results: Of potentially 11,520 surfaces, 3,015 occlusal and 5,112 approximal surfaces were analysed. *Occlusal*: Of 907 unrestored surfaces, 110 had primary caries and 53% were detected radiographically. A total of 183 of 2,108 restored surfaces had caries adjacent to restorations, and 99% were found radiographically. A total of 190 restorations were over/under-extended, and 89% were registered radiographically. *Approximal:* Of 2,649 unrestored surfaces 648 had primary caries, and 92% were registered radiographically. A total of 565 of 2,463 restored surfaces had caries adjacent to restorations, and 99% were found radiographically. A total of 638 restorations were over/under-extended, and 98% were found radiographically. For all restorations, material and depth influenced quality of restorations and incidence of caries adjacent to restorations. At least one independent variable (gender/age group/tooth-type/jaw/side/mesial-distal surface) influenced frequencies of primary caries, caries adjacent to restorations and quality of restorations.

Conclusions: First-time clinical examination must be supplemented with X-rays to obtain a complete impression of caries status in posterior regions regarding diagnostics of caries, assessment of lesion depth and quality of restorations.

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Introduction

Precisely detecting occurrence and activity of primary and caries adjacent to restorations lesions at various stages is important for initiating prophylactic and minimal invasive caries treatment strategies of early caries lesions, to limit extension of traditional restorative treatments, and to avoid pulp damage caused by restorative treatment [1,2]. Early caries detection is also important for estimating optimal control intervals for patients [3,4].

In the anterior regions, clinical caries detection has high sensitivity and specificity, because of the morphology of teeth and accessible approximal spaces. In the posterior regions, the complex morphology of occlusal surfaces implies diagnostic challenges. The width of the approximal surfaces and gingival location of contact areas between synergist teeth make it difficult to detect initial caries lesions at clinical examination.

Previous studies have shown that clinical assessment of early occlusal and approximal dentine caries lesion in the posterior regions has low sensitivity but relatively high specificity [5–7]. It means that caries lesions might be overlooked by clinical-tactile examination. Bitewing radiographs (BWs) are the most often used supplementary tool to clinical examination in detection of primary caries and caries adjacent to restorations lesions especially on approximal surfaces [8,9]. Radiographical detection of all types of dentine caries has high specificity with limited risk of false positive diagnosis [10,11]. Furthermore, radiographical assessment has higher sensitivity but lower specificity in detecting cavitation on approximal surfaces compared to clinical assessment [12]. In a systematic review, it was reported that radiographs were more accurate than tactile detection of approximal caries adjacent to restorations with limited risk of false-positive diagnoses [1].

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Clinical caries status in a Danish adult population was measured in a previous study (Danish Health Examination Survey 2007–2008, DANHES) comprising 4,402 individuals [13]. Based on recordings from a sub-population of 240 individuals from that study, we aim to compare the clinical and radiographical caries registrations to specify the additional information that X-rays gives to a first-time clinical examination in the present population. Furthermore, the influence of various factors on the clinical and radiographic caries registrations will be analysed.

Materials and methods

A clinical examination supplemented with BWs was performed in a cross-sectional study in 2007–2008. The original study population comprised 4,402 individuals from 18 to 83 years old in 13 municipalities in Denmark. The study was conducted in accordance with the Helsinki Declaration and approved by the Ethical Committees for the Region of Copenhagen (Journal number: H-C-2007-0118). Written informed consent was obtained from all participants [13].

For this study, a subsample consisting of 240 patients equally distributed with 20 females and 20 males from each of six age groups was randomly selected from the original 4,402 individuals [14]. Clinical and radiographical scorings were registered on occlusal and approximal surfaces on first and second premolar and first and second molar teeth in upper and lower jaws. The surfaces were scored clinically as well as radiographically as being unrestored (sound or with primary caries) or being restored (without or with caries adjacent to restorations). The material type of restoration was also recorded clinically and radiographically, and when registrable the quality was scored as sufficient or insufficient in cases of over-extended or under-extended restoration. The radiographic depth of primary caries and caries adjacent to restorations lesions as well as restorations were scored as lesion/restoration in enamel/EDJ, outer, middle, or inner third of dentine. One experienced external examiner made all radiographical scorings in a dark room using a calibrated Olorin AB© monitor. In order to calculate the intra-examiner reliability, the examiner made 7% of the radiographical scorings twice within two weeks interval.

Statistical analyses

Of the potential 11,520 surfaces (240 patients × 4 quadrants × 4 occlusal plus eight approximal surfaces) a total of 3,393 (29%) surfaces had to be excluded: 1,305 (11%) due to lack of clinical or radiographical registrations of surfaces, 1,709 (15%) due to overlapping or not visible surfaces on BW and 379 (3%) due to incompatible clinical and radiographical registrations of restored surfaces. Thus, a total of 8,127 (71%) surfaces with reliable clinical as well as radiographical scorings were included in the statistical analyses.

Bivariate chi-square and Fisher Exact tests were used for comparing clinical and radiographical assessments and analysing the influence of the independent categorical variables gender, age group, tooth type, surface, jaw and side on clinical and radiographical registrations (Tables 1 and 2). For analyses of caries adjacent to restorations and insufficient restorations two additional independent variables were added, i.e. restorative material and restoration quality. In the bivariate analyses, sound surfaces were compared with all other surfaces, surfaces with primary caries were compared with sound surfaces exclusively, restored surfaces were compared with all other surfaces, and surfaces with caries adjacent to restorations were compared with restored surfaces without caries exclusively. The significance level was set at 0.05. SPSS version 25 (IBM, Chicago, IL) was used for the analyses.

Table 1. Distribution of included ($n = 8127$) and excluded ($n = 3393$) surfaces in relation to six variables.

Variable	Category	Included *n* (%)	Excluded *n* (%)	*p* Value
Gender	Male	4,100 (71)	1,660 (29)	0.14
	Female	4,027 (70)	1,733 (30)	
Age group	19–34 years	1,435 (75)	4,85 (25)	**<.001**
	35–44 years	1,408 (73)	512 (27)	
	45–54 years	1,422 (74)	498 (26)	
	55–64 years	1,386 (72)	534 (28)	
	65–74 years	1,348 (70)	572 (30)	
	75–83 years	1,128 (59)	792 (41)	
Tooth type	1. premolar	1,624 (56)	1,256 (44)	**<.001**
	2. premolar	2,294 (76)	586 (20)	
	1. molar	2,159 (72)	721 (25)	
	2. molar	2,050 (69)	830 (29)	
Surface	Occlusal	3,015 (79)	825 (21)	**<.001**
	Mesial	2,465 (64)	1,375 (36)	
	Distal	2,647 (69)	1,193 (31)	
Side	Right	4,134 (70)	1,767 (30)	0.24
	Left	3,993 (71)	1,626 (29)	
Jaw	Upper	4,092 (71)	1,668 (29)	0.25
	Lower	4,035 (70)	1,725 (30)	
Total	–	8,127 (71)	3,393 (29)	11,520

Bolded figures highlight significant difference in variables among in and excluded case.

Results

The inter- and intra-examiner kappa coefficients ranged between 0.85 and 0.93 for clinical caries registrations showing strong to almost perfect agreement for the original study population [13]. The overall intra-examiner kappa value for radiographical scoring was 0.70 presenting a moderate agreement between the first and second registrations.

Occlusal surfaces, n = 3,015

Unrestored, sound surfaces: clinical n = 855 (28%) and radiographical n = 830 (27%)

Clinical and radiographical registrations of sound occlusal surfaces showed a high level of agreement (90%) (Figure 1(A), Tables 2 and 3) [14]. Only, 7% were exclusively found clinically and 4% exclusively on X-rays. Sound surfaces comprised approximately one-fourth in females and one-third in males ($p < .001$). Around two-thirds of the occlusal surfaces in 19–34-year-olds were sound clinically and radiographically compared to only 10% in patients above 65 years ($p < .001$). First, premolars had the highest (50%) and first molars the lowest (9%) frequency of sound surfaces ($p < .001$). Approximately, 10% higher frequency was registered in lower

Table 2. Clinical and radiographical distribution of unrestored surfaces (sound/primary caries) and restored surfaces (without and with caries) according to different independent variables in 8,127 occlusal and approximal surfaces in 240 patients.

			Unrestored surfaces ($n = 3,556$)				Restored surfaces ($n = 4,571$)			
			Sound		Primary caries		Without caries		With caries	
Variable	Category	*n*	Clinical	X-ray	Clinical	X-ray	Clinical	X-ray	Clinical	X-ray
Gender	Male	4,100	1,880	1,544	63	399	2,154	1,751	3	406
	Female	4,027	1,570	1,323	43	290	2,411	2,074	3	340
Age group	19–34 years	1,435	1,115	936	32	211	2,88	224	0	64
	35–44 years	1,408	871	726	13	158	523	455	1	69
	45–54 years	1,422	588	505	19	102	814	717	1	98
	55–64 years	1,386	393	317	15	91	977	816	1	162
	65–74 years	1,348	276	217	15	74	1,056	876	1	181
	75–83 years	1,128	207	166	12	53	907	737	2	172
Tooth type	1st premolar	1,624	984	820	10	174	630	517	0	113
	2nd premolar	2,294	1,071	864	19	226	1,203	996	1	208
	1st molar	2,159	548	415	23	156	1,585	1,314	3	274
	2nd molar	2,050	847	768	54	133	1,147	998	2	151
Surface	Occlusal	3,015	855	830	52	77	2,107	1,926	1	182
	Mesial	2,465	1,256	982	20	294	1,187	961	2	228
	Distal	2,647	1,339	1,055	34	318	1,271	938	3	336
Jaw	Upper	4,092	1,595	1,297	46	344	2,447	2,016	4	435
	Lower	4,035	1,855	1,570	60	345	2,118	1,809	2	311
Side	Right	4,134	1,761	1,434	54	381	2,314	1,931	5	388
	Left	3,993	1,689	1,433	52	308	2,251	1,894	1	358
	Total	**8,127**	**3,450**	**2,867**	**106**	**689**	**4,565**	**3,825**	**6**	**746**
Restorative material	Amalgam	2,374	–	–	–	–	2,370	2,016	4	358
	Composite	953					952	727	1	226
	Ceramic	692					692	620	0	72
	Gold	524					523	436	1	88
	Unknown	28					28	26	0	2
Quality of restoration	Sufficient		–	–	–		4,537	3,684	0	86
	Insufficient						28	141	6	660
	Total	**4,571**	–	–	–	–	**4,565**	**3,825**	**6**	**746**

jaw compared to upper jaw teeth ($p < .001$). No differences were found in relation to side.

Unrestored occlusal surfaces with primary caries: clinical n = 52 (2%) and radiographical n = 77 (3%)

The agreement level between clinical and radiographical findings of primary caries was only 17% [14]. As many as 53% of the lesions were only visible on X-rays, and 30% were only registered clinically. Of 49% of primary lesions were limited to enamel/EDJ and only 8% were in the inner 2/3 in the dentine. Primary caries were dominant in males, upper jaw, and right-side teeth on radiographs but not in clinical assessments ($p < .03$). With both assessments, primary caries was most dominant in 19–34-year-olds ($p = .01$), most frequent in second molar teeth, and least in second premolar teeth ($p < .001$).

Restored occlusal surfaces: clinical and radiographical n = 2,108 (70%)

Only occlusal surfaces recorded as restored clinically as well as radiographically were included in the analyses [14]. The frequency of restored surfaces was higher in females (74%) than males (66%) ($p < .001$). The occurrence was doubled from 30% among the 19–34-year-olds to 59% among the 35–44-year-olds, and further increased to 89% among the >65–year-olds ($p < .001$). Significantly, fewer premolar teeth were restored compared to molars ranging from 46% in first premolars to 88% in first molars ($p < .001$). Most restored teeth were found in the upper jaw (73% *vs.* 37%), ($p < .001$). No differences were found in relation to side.

Restored occlusal surfaces with caries adjacent to restorations: clinical n = 1 (0%) and radiographical n = 182 (9%)

Except for a single lesion, all caries adjacent to restorations were detected on X-rays (99%) [14]. There was an age-related but unsystematic variation in the incidence of caries adjacent to restorations ($p = .001$). The frequency was highest (16%) among the youngest 19–34-year-olds and lowest (6%) among 45–54-year-olds. Caries adjacent to restorations appeared most frequently in restored upper jaw teeth (9% *vs.* 7%), ($p = .04$) [14]. Presence of caries adjacent to restorations did not differ according to gender, tooth type and side.

Restorative material as well as restoration depth influenced the incidence of caries adjacent to restorations ($p = .01$). Adjacent caries was recorded in 14% of composite, 6% amalgam and 9% gold and metal-ceramic restorations ($p = .001$). The depth of restoration and caries adjacent to restorations could be determined for 380 resin composite and 1161 amalgam restorations. Only 6% of amalgam and 5% resin restorations were limited to enamel/EDJ; 40% of amalgam and 31% resin restorations were in the outer third of dentine; 35% amalgam and 35% resin restorations were in the middle third of dentine; and 19% amalgam and 27% resin restorations were in the inner third of the dentine ($p = .002$). Caries adjacent to restorations were exclusively (99%) found in dentine almost equally distributed in each zone for both materials ($p > .05$).

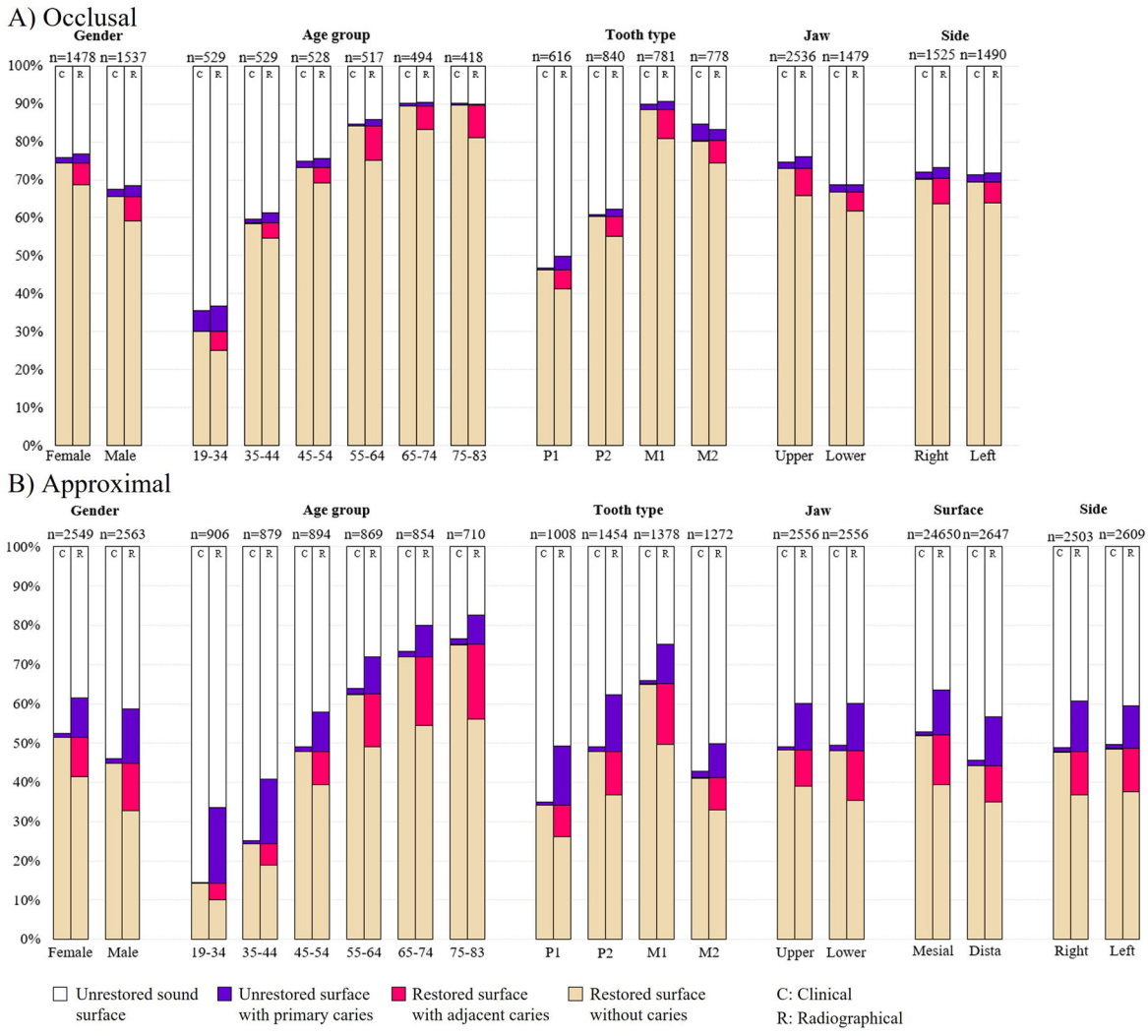

Figure 1. Distribution of sound, carious and restored occlusal and approximal surfaces.

Table 3. Agreement level between clinical and radiographical registrations on occlusal and approximal surfaces.

	Registrations	Occlusal	Approximal
Not restored surfaces		**Sound**	**Sound**
		***n* = 888**	***n* = 2,631**
	Clinical and radiographical	797 (90%)	2001 (76%)
	Clinical exclusively	58 (7%)	594 (23%)
	Radiographical exclusively	33 (4%)	36 (1%)
		Primary caries	**Primary caries**
		***n* = 110**	***n* = 648**
	Clinical and radiographical	19 (17%)	18 (3%)
	Clinical exclusively	33 (30%)	36 (6%)
	Radiographical exclusively	58 (53%)	594 (92%)
Restored surfaces		**Caries adjacent to restoration**	**Caries adjacent to restoration**
		***n* = 183**	***n* = 565**
	Clinical and radiographical	0 (0%)	2 (0%)
	Clinical exclusively	1 (1%)	3 (1%)
	Radiographical exclusively	182 (99%)	562 (99%)
		Insufficient restoration	**Insufficient restoration**
		***n* = 190**	***n* = 638**
	Clinical and radiographical	3 (2%)	9 (1%)
	Clinical exclusively	18 (9%)	4 (1%)
	Radiographical exclusively	169 (89%)	625 (98%)

Restored occlusal surfaces with insufficient restorations: clinical n = 21 (1%) and radiographical n = 172 (8%)

Majority (89%) of over- and under-extended insufficient occlusal restorations were only seen on X-rays. The frequencies in radiographs were 6% in females and 11% in males ($p < .001$). Insufficient restorations were highest in 55–64 and 75+ year-olds (10–11%) compared to 6% in the other age groups ($p = .04$). Tooth type, jaw and side did not influence the occurrence. Quality of the restorations was associated with the material type with the lowest insufficiency for amalgam (6%) compared to 11–12% for resin composite, gold, and metal-ceramic restorations ($p = .001$). Caries adjacent to restorations were registered for insufficient restorations in resin (11%), amalgam (5%), gold (9%) and metal-ceramic (9%), ($p = .001$). Caries adjacent to restorations were also registered in 4% of sufficient resin, 1% amalgam but no gold or metal-ceramic restorations ($p < .05$).

Approximal surfaces, n = 5,112

Unrestored, approximal sound surfaces: clinical n = 2,459 (51%) and radiographical n = 2,037 (40%)

Clinical and radiographical registrations of sound approximal surfaces showed a good agreement level of 76% (Figure 1(B), Tables 2 and 3). Further, 23% were exclusively found clinically and 1% on X-rays. Both clinically and radiographically, frequency of sound surfaces was highest in males ($p < .04$). Around 85% of approximal surfaces in 19–34-year-olds were sound clinically while it was only 66% on radiographs. The frequency was reduced to 23% clinically and 17% radiographically in patients above 75 years ($p < .001$). First premolars had the highest and first molars the lowest frequency of sound surfaces ($p < .001$), and the highest frequency was registered in the lower jaw ($p < .001$). No differences were found regarding the mesial/distal surfaces or side.

Unrestored approximal surfaces with primary caries: clinical n = 54 (1%) and radiographical n = 612 (12%)

Almost all (92%) primary caries lesions were visible on X-rays exclusively, and the agreement level between clinical and radiographical findings was only 3% [14]. Of 81% of the primary caries lesions were limited to enamel/EDJ and only 4% were in the middle or inner third of dentine. The frequency of primary caries on radiographs was 25% in males and 21% in females ($p = .01$). Clinically, 0% (3) primary approximal caries lesions were registered in 19–34-year-olds, while it was 23% on radiographs. The frequency increased to 6% clinically and 30% radiographically in patients above 75 years ($p < .02$). Second premolars and first molars had the highest frequency of primary caries registered on radiographs ($p < .001$). There were no differences with regard to jaw, side and mesial/distal surfaces neither clinically nor radiographically.

Restored approximal surfaces: clinical and radiographical n = 2,463 (48%)

Only approximal surfaces recorded as restored clinically as well as radiographically were included in the analyses. The frequency of restored surfaces was 52% in females and 45% in males ($p < .001$). The occurrence was lowest among 19–34-year-olds (14%) and highest (75%) among patients above 75–years ($p < .001$). Restored surfaces were less frequent in first premolars (34%) and most in first molars (65%), ($p < .001$). Upper jaw teeth were restored in 52% compared to 44% in lower jaw ($p < .001$). We found no differences in relation to mesial/distal surfaces or side. These patterns were the same for amalgam and resin composite restorations as well as for ceramic and gold crowns.

Restored approximal surfaces with caries adjacent to restorations: clinical n = 5 (0%) and radiographical n = 564 (23%)

Almost all caries adjacent to restorations were found on radiographs (99%) [14]. Presence of caries adjacent to restorations was 27% in males compared to 19% in females ($p < .001$). Similar to results for occlusal surfaces, we found an age-related but unsystematic variation in the incidence of caries adjacent to restorations ($p = .02$). The highest frequency was among the 19–34-year-olds (29%) and the lowest among the 45–54-year-olds (18%). Caries adjacent to restorations were higher on distal (26%) than mesial (19%) surfaces ($p < .001$), while no differences were found between tooth type, jaw, or side.

The depth of restorations and caries adjacent to restorations could be determined for 363 resin composite, 1,106 amalgam, 1 metal-ceramic and 10 gold restorations. Only 1% of amalgam and 2% resin restorations were limited to enamel/EDJ; 30% of amalgam and 31% resin restorations were <1/3 in dentine; 45% of amalgam and 36% resin restorations were 1/3–2/3 in dentine; and 24% amalgam and 31% resin restorations were in the inner third of the dentine ($p < .001$).

Restored approximal surfaces with insufficient restorations: clinical n = 13 (1%) and radiographical n = 629 (26%)

The quality of approximal restoration was determined for 490 resin composite, 1,169 amalgam, 456 metal-ceramic and 345 gold restorations. Nearly all (98%) of the over- and under-extended insufficient approximal restorations were seen on X-rays exclusively. The frequency of insufficient restorations in radiographs was 31% in males and 20% in females ($p < .001$). Insufficient restorations were more frequent on first molars (39%) and lowest on first premolar (17%) and second molars (17%), ($p = .007$). Of the restored distal surfaces 29% were insufficient compared to 21% of the restored mesial surfaces ($p < .001$). No differences were found in regard to age group, side or jaw. The occurrence of insufficient restorations was associated to material type with the lowest occurrence for metal-ceramic (15%) compared to 25% for gold, 26% for amalgam and 34% for resin restorations ($p < .001$). Caries adjacent to restorations were registered for insufficient composite (21%), amalgam (29%), metal-ceramic (11%) and gold (20%) restorations ($p = .001$). Caries adjacent to restorations were also registered in 5% of sufficient resin,

3% amalgam and <0.2% of gold or metal-ceramic restorations ($p < .001$).

Discussion

The original study population in Denmark showed an over-representation of dentulous people with greater interest in their dental health compared to the national adult population of Denmark. The participants had a higher level of oral hygiene habits and somewhat lower caries experience compared to other epidemiological Denmark studies from the same decade [13,15,16]. X-rays were taken along with the clinical examination in 2007–2008 in a fully equipped dental clinic and data on clinical findings were collected according to fixed criteria. Only patients with digital radiographs of adequate quality were included in this study. The inter- and intra-examiner kappa coefficients ranged between strong to almost perfect for clinical caries registrations. The intra-examiner kappa coefficients for X-ray registrations of caries and restorations were moderate. By randomization and stratification of age and gender in the selection of 240 patients for this study, we believe that we obtained a fairly accurate impression of the value of supplementing a first-time clinical study of adult dentulous patients with bitewing recordings. The marked discrepancies between the clinical and radiological findings reflect the results from other studies [17–19]. It is conceivable that such inconsistency virtually always will occur on first-time examinations of patients in dental practices. Therefore, paralleling the clinical and radiological findings of a first-time examination is crucial to minimize false-positive and false-negative findings and choose optimal treatment measures.

Dental cleaning before clinical examination is strongly recommended to enable diagnosis of initial non-cavitated enamel lesions particularly on occlusal surfaces and to evaluate lesion activity [8]. In a recently published clinical study on adults between 16 and 32 years old where the teeth were cleaned before clinical examination. In that study, X-ray contributed with only 27% of the primary occlusal lesions and 66% of the approximal lesions [17]. In this study, Möller's diagnostic criteria were used and no plaque removal was performed before clinical registrations [20]. This may explain why 53% of the occlusal and 92% of approximal primary caries lesions were only found radiographically, exclusively. A previous study analysing radiographical yields to clinical caries diagnosis in the permanent dentition in adults without tooth cleaning showed similar tendencies with 55% of the occlusal and 77% of approximal caries lesions solely found in radiographs [21]. Other studies have also reported noticeable yield of radiographs in posterior regions but no differentiation in surface level was mentioned [18,19]. Bearing in mind that the supplementary information by BW radiographs were in patients with superior dental health than the average Danish patients, the impact of BWs may be expected to be even higher in patients with average or high caries risk. Studies regarding X-rays taken in relation to patient's caries risk are not available.

Assessment of caries lesion activity is a natural part of caries registrations and diagnostics and an essential aspect of treatment decisions. At first-time consultation, radiographs do not contribute to activity assessment of caries lesion and both active and inactive caries lesions registers on X-rays. In the contrary, it might be possible to differentiate activity status on cleaned teeth in a first-time clinical examination and therefore less caries lesions will be registered clinically. Activity assessment on radiographs can only be performed when lesions and restorations are monitored over time.

Caries adjacent to restorations are one of the main justifications for providing invasive interventions [2]. Bitewings are the mainly used method to detect caries adjacent to restorations lesions in approximal surfaces [22–24]. Accordingly, almost all caries adjacent to restorations lesions both on approximal but also occlusal surfaces were diagnosed on radiographs and 99% of all caries adjacent to restorations lesions were in dentine in our study. Part of the explanation may be attributed to the lack of plaque removal. Another reason may be that it has become clear that marginal discolorations are not identical with caries adjacent to restorations and rarely require operative intervention. This has led to intensified efforts in pre- and post-graduate teaching and has probably changed the diagnostics with a less frequent clinical recording of caries adjacent to restorations as a result [2]. In our study, both recurrent and residual caries were registered as caries adjacent to restorations.

In accordance with existing literature, we found that the occurrence of caries adjacent to restorations was significantly higher in resin restorations compared to amalgam and indirect ceramic and gold restorations [2,25]. Caries adjacent to restorations is even higher in patient with medium or high caries risk [26]. However, the use of amalgam is significantly decreased and knowledge about long-term effectiveness of the materials replacing amalgam in different types of cavities is still inadequate [27].

The strength of our study is that we have an equal distribution between males and females, and between six age groups from 18 to 83 years old. It is worth knowing that the number of sound surfaces was significantly highest in males clinically as well as radiographically and the number of restored surfaces was significantly highest in females (60% *vs.* 53%). Further, the percentages of primary and caries adjacent to restorations as well as insufficient restorations were lowest in females, although the difference in caries adjacent to restorations was not significant (Figure 1, Table 2). These patterns could be explained by the fact that women in general visit dentists more often than men [28]. However, the age-related differences were far greater than the differences between male and females. As shown in Figure 1 and Table 2, the percentages of restored surfaces showed a great increase from 20 to 57% in the youngest age groups (19–54 years old) but only a moderate increase from 71% to 81% in patients above 55 years of age. Also, the incidence of primary caries and caries adjacent to restorations differed in relation to age. Primary caries were most prevalent in the youngest age groups (19–54 years old), while caries adjacent to restorations were most common in the oldest age groups

(55–83 years old). As these results are based on clinical as well as radiographical registrations, they underline the importance of including X-ray diagnostics in epidemiological studies of caries incidence.

According to data from the National Board of Health in Denmark, each adult Danish patient had 0.79 intraoral radiographs taken in the year 2000, rising to an average of 0.85 radiographs in the year 2002 [29]. As the majority of the X-rays were known to be bitewings, this means that bitewings were taken at almost three-year intervals on adult patients in Denmark. This was in line with ADA's 2004 recommendations for fully and partially dentate adult patients [30]. The applicable 2004 guideline issued from the National Board of Health in Denmark advises dental practitioners to use supplementary X-ray diagnostics based on the patient's caries status and risk assessment instead of fixed intervals between X-rays [31]. Further, the clinician shall also perform a thorough clinical examination combined with anamnestic information of the patient, and review any prior radiographs in order to perceive the patient's dental and general health status and then decide if new X-rays are necessary [30].

Our findings demonstrate that caries burden is a persisting challenge until the middle age while the carious related treatments thereafter mostly comprise renovation, reparation and replacement of previously restored surfaces due to caries adjacent to restorations and insufficient restorations. Moreover, the majority of the approximal caries lesions that were overlooked in the clinical examination were initial lesions that could be treated non-operatively if they were diagnosed by additional radiographical examination. In a clinical point of view, performing only clinical examination results in neglected diagnosed caries and dental status of the patient (Figure 1). Combined diagnostic methods improve the accuracy of diagnostics and leading to minimized risk for overtreatment of dental caries. Number of standardized clinical studies on recently developed diagnostic tools, such as Laser Fluorescence, Fibre-optic transluminations and digital scanning is limited. Additional studies are needed before they are commonly used tools in dental clinics as well as in epidemiological studies [32].

Bias and deviation in clinical studies are reported [24]. Concerns about false positive caries registration in radiographs have been raised in decades due to the threat for overtreatment [33]. Taken radiographs with caries risk-based intervals will decrease the risk of false-positive findings and ensure against neglected caries status due to overlooked lesions when radiographs are not used [1]. In order to reduce the number of X-rays, temporary tooth separation has been suggested to improve access to the approximal surfaces and evaluate the enamel integrity [34]. However, separation is not an applicable tool in all patients, and monitoring lesion behaviour may still rely on radiograph, with its inaccuracies and observer variations taken into account [35].

Conclusions

Our study shows that radiological diagnostics is a crucial required supplement to clinical caries diagnosis in all age groups. A first-time clinical examination must be supplemented with intraoral X-rays to obtain a complete impression of caries status in the posterior regions, i.e. the occurrence of primary and caries adjacent to restorations lesions as well as assessment of lesion depth and quality of the restorations. The benefit of radiographs is highest for approximal surfaces but even necessary for complete diagnostics of occlusal surfaces. Radiographs yield to minimize overlooked primary caries lesions in younger patients and caries adjacent to restorations lesions in middle-aged and elderly patients.

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Disclosure statement

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Data availability statement

The research data that support the findings of this study are not publicly available due to their containing information that could compromise the privacy of research participants.

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