The sensitivity and specificity of clinical assessment compared with bitewing radiography for detection of occlusal dentin caries

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Abstract

Purpose: *This prospective, cross-sectional study examined the sensitivity and specificity of clinical assessment compared to bitewing radiographs in the detection of occlusal dentin caries in permanent molars.*

Methods: *Subjects were 481 children aged 5 – 12 years from a school-based dental clinic. Occlusal surfaces of 1929, sealed and unsealed first and second permanent molars were examined clinically and scored using specific criteria. Teeth with any type of restorations or proximal caries, including preventive resin restorations, were excluded from the study. Bitewing radiographs were exposed within 4 weeks of clinical examination and were assessed for dentin radiolucencies beneath the occlusal surface. The results of the clinical examinations were correlated with those of bitewing radiographs. Information provided by the parents on history forms, including systemic fluoride exposure, was also noted.*

Results: *Of the 1833 teeth scored as clinically sound in the study, only 72 (4%) demonstrated a dentin radiolucency on bitewings, and 1761 (96%) were scored as sound. The sensitivity of the clinical examination was determined to be 0.96. In the teeth clinically scored as showing dentin caries, only 56/96 (58%) were found to have dentin radiolucencies on the radiographs. The specificity of the technique was determined to be 0.58. A positive history of a medical condition, or fluoride exposure, in the forms of toothpaste use, or water fluoridation did not affect the examination results*

Conclusions: *Clinical examination of cleaned and dried, sealed, and unsealed teeth has a sensitivity of 0.96 and a specificity of 0.58 in the detection of dentin radiolucencies in bitewing radiographs. Dentin radiolucencies beneath clinically sound occlusal surfaces are not significantly associated with gender, medical conditions or fluoride. (Pediatr Dent 23:204-210, 2001)*

As occlusal caries accounts for a large proportion of all new carious lesions in children and adolescents,[1-3] its diagnosis is of significant clinical importance. However, in spite of the fact that occlusal surfaces of molars and premolars are directly visible clinically, many studies have shown that a clinical examination may fail to detect anywhere between 0.8 to 50% of radiographic occlusal dentin lesions.[4-11] Among fissure-sealed permanent molars, the proportion of radiographically detected occlusal dentin lesions may even be as high as 32 to 58%.[10,12] Occult or hidden caries[13-18] have been used to describe such radiographic lesions immediately beneath clinically sound occlusal surfaces of molars and premolars.

Besides visual inspection and radiography, several diagnostic instruments are currently available to detect occlusal caries, such as fiber optic transillumination and electrical resistance measurements. A recent meta-analysis comparing these techniques reported that electrical resistance measurements gave the highest values for sensitivity and specificity, whereas visual inspection techniques performed the worst and fiber optic transillumination in between. On the other hand, if clinical results were compared with histology, visual inspection after air drying, showed the best outcomes.[26] These results are supported by recent studies which suggest that visual techniques which employ air drying, and detailed inspection of the enamel is highly accurate in the diagnosis of early enamel lesions.[5, 30]

Bitewing radiography has also been compared with other diagnostic methods such as electrical resistance measurements and light-induced fluorescence in occlusal caries diagnosis.[25-28] Although the value of bitewing radiography, when used alone, is thought to have relatively low sensitivity in occlusal caries diagnosis, its accuracy is greatly improved when used in conjunction with other techniques, such as visual-tactile examination.[21,22,29-31]

It was hypothesized that while a detailed visual-tactile examination technique can detect the majority of occlusal lesions which involve dentin, there remains a proportion which is difficult to diagnose using inspection alone, and that this may be detectable using radiography. The purpose of this prospective, cross-sectional study was, therefore, to compare the sensitivity and specificity of a visual-tactile clinical examination of occlusal surfaces compared to bitewing radiography in detecting dentin radiolucencies. As it was not possible to perform histology to determine the true status of the lesions in studies in children, bitewing radiography was considered the "standard" technique for determining the accuracy of diagnosis of the clinical scores.

Methods

Subjects

The subjects were school children aged 5 to 12 years attending a school dental clinic in Brisbane, Australia, between April

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Table 1. Assessment of the status of the occlusal surface of sealed and unsealed molar teeth (modified from Ekstrand et al [30,31])

Caries Score	Description
C0 (Non-carious)	Absence of all features below
C1 (Suspected enamel caries)	Pit/fissure discoloration only visible after air drying
C2 (Enamel caries)	Pit/fissure demineralization only (a white zone along the fissure margins), visible after air drying
C3 (Enamel caries)	Pit/fissure discoloration and demineralization of the occlusal surface, visible without air drying
C4 (Early dentin caries)	Small perceptible break in the occlusal surface detectable as an explorer 'catch' or presence of grayish discoloration from the underlying dentin
C5 (Established dentin caries)	Frank cavitation into occlusal dentin
Sealant Score	
F0 (Intact sealant)	No visible loss of occlusal sealant
F1 (Partial loss, caries absent)	Partial loss of sealant and absence of occlusal caries
F2 (Partial loss, caries present)	Partial loss of sealant with frank cavitation into dentin
Radiographic Score	
R0	No radiolucency in dentin
R1	Radiolucency in the outer third of dentin thickness
R2	Radiolucency extending to two thirds of dentin
R3	Radiolucency extending the full thickness of dentin

1999 and March 2000. All subjects who required a dental examination during the time period were selected for inclusion in the study. The radiographs were exposed as part of the standard examination procedure for children at the school clinic. Parental consent for routine clinical and radiographic examination was obtained before dental examination. Approval for the study was obtained from the Human Ethics Committee of the University of Queensland. The consent rate for the examination was approximately 74%, which reflected the general consent rate for examination at the clinic.

Information provided by the parents on the routine personal history forms, including exposure to water fluoridation, fluoride supplementation, age at commencement of fluoride toothpaste, and medical history was noted. Operators were blinded to the personal details of each patient with respect to both the clinical examination and assessment of bitewing radiographs.

Clinical assessment of molar teeth

Unsealed teeth

The teeth examined were erupted permanent first and second molar teeth. Teeth in each subject were examined and scored by one of five operators with respect to the appearance of the occlusal surface after thorough air drying (> 5 s) using the dental triplex syringe, Hu-Friedy sickle explorer (Chicago, Illinois) and dental mirror. The occlusal surfaces were dried carefully and visually inspected and the translucency and breakdown of enamel and fissure coloration noted. Standardized fissure criteria which were a modification of the system of Ekstrand et al[30,31] were used for scoring each occlusal surface (Table 1).

Sealed teeth

Where occlusal surfaces were fissure sealed, teeth were scored according to set sealant criteria (Table 1). Completely missing sealants were scored according to non-sealed fissure criteria.

Subjects' dental charts were examined to check whether the teeth had previous history of operative intervention, such as invasive sealing or preventive adhesive restoration. Only the molars without a history of operative intervention were included in the study. Furthermore, teeth were also excluded from the study if they showed caries on non-occlusal surfaces (such as buccal, lingual, and interproximal) and restorations, as well as enamel hypoplasia.

Radiographic techniques and assessment

Conventional bitewing radiographs were exposed immediately after the clinical examination, or within 4 weeks of the clinical examination. Bitewing radiographs were performed using the Phillips Oralix 65s and DensOMat apparatus (65kVp, 7.5mA, 50/60Hz, 240V, GENDEX, Des Plaines, IL). Size 22 mm x 35mm Super Poly-Soft Kodak Ultraspeed film (Eastman Kodak Company, Rochester, NY, USA) and Rayvue Bitewing Film Holders (Xray Supplies Pty Ltd, Hornsby NSW, Australia 2077) were employed for an exposure time of 0.42 secs, and processed manually according to manufacturer's guidelines.

Table 2. Intra- and inter-operator variability for the clinical assessment of molar teeth

Operator	Intra-operator variability		Inter-operator variability	
	Weighted Kappa statistic	95% CI	Mean Weighted Kappa statistic*	95% CI
1	1.0	1.0 – 1.0	0.79	0.59 – 0.98
2	0.93	0.78 – 1.0	0.70	0.45 – 0.93
3	0.82	0.61 - 1.0	0.75	0.53 – 0.96
4	0.93	0.79 – 1.0	0.72	0.51 – 0.94
5	0.96	0.90 - 1.0	0.74	0.51 – 0.95
Overall	**0.94**	**0.73 – 1.0**	**0.84**	**0.75 – 0.94**

* Mean of Weighted Kappa statistic for comparisons of that operator with each of the remaining four operators.

Scoring of bitewing radiographs

Bitewing radiographs were assessed by one of the authors (MSF) under 2X magnification in a dark room using a standard radiographic illuminating box, and peripheral light blockout. The teeth were scored with regard to whether dentin radiolucency beneath the occlusal enamel was present or absent (Table 3). During the radiographic assessment of the teeth, the operator was blinded to the results of clinical assessment.

Special attention was also made to ensure that true occlusal radiolucencies in dentin were distinguished from buccal pits, which usually show a vertical linear radiolucency.

Definition of "clinically sound"

The term "clinically sound" was applied after the clinical examinations, and referred to those occlusal surfaces which were judged as not to have dentin caries. For the purpose of analysis, this term applied to the clinical scores of C0-C3 for unsealed molars and sealant scores F0 and F1 for the sealed molars (Table 1).

Standardization of techniques and statistical analysis

Prior to the clinical examinations, the five operators were trained and standardized with respect to both the clinical methodology, and clinical scoring systems, using 10 extracted third molar teeth stored in saline. These teeth represented each of the different appearances of the occlusal surface of both unsealed and sealed teeth (Table 1). They were examined twice by all five examiners on two separate occasions for the purpose of determining intra- and inter-operator variability (Table 2). The Weighted Kappa scores[32] were estimated at 0.94 and 0.84 respectively.

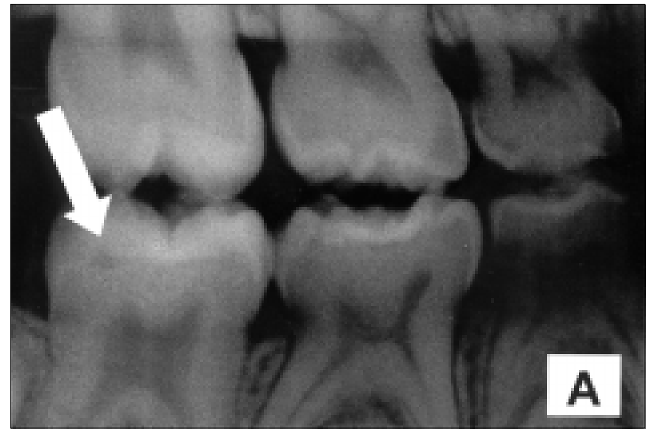

Fig 1A. Occlusal dentin radiolucency on a bitewing radiograph.

Intra-operator variability for the radiographic assessment was determined for one of the authors (MSF), who performed all the radiographic scoring. For this test of intra-operator variability, the scoring was performed on two separate occasions using 10 sets of bitewing radiographs that were not part of the present study. The Weighted Kappa score for intra-operator variability was 1.0

Data were analyzed using the statistical package SPSS-PC Version 10.0 (SPSS Inc, 2000 Chicago, Illinois). Pearson's Chi-square test, the Student's t-test, and the t-test on natural log were used to determine statistical differences between groups. The alpha value was placed at 0.05.

Table 3. Demography of subjects and prevalence of dentin radiolucency

Occlusal Dentin Radiolucenciesin Teeth Clinically Scored as Sound				
Subjects	**Present** N (%)	**Absent** N (%)	**Total** N (%)	***P*-value**
Total Number	48 (10%)	433 (90%)	481(100%)	(95% CI: 8%–13%)
Gender Subjects:				
Male	28 (11%)	237 (89%)	265 (55%)	N.S.
Female	20 (9%)	196 (93%)	216 (45%)	
Teeth:				
Male	44 (4%)	993 (96%)	1037 (54%)	N.S.
Female	28 (3%)	864 (97%)	892 (46%)	
Age at examination				
Mean (yrs ± SD)	8.7 ± 2.0	8.0 ± 2.2	8.1 ± 2.2	
Range (yrs)	5 - 12	6 - 12	5 - 12	
Medical Condition				
Total with positive medical history N(%)	10 (21%)	108 (25%)	118(25%)	N.S.
Fluoride supplementation				
Yes	12 (25%)	87 (20%)	99(21%)	N.S.
No	36 (75%)	346 (80%)	382(79%)	
Commencement of toothpaste use				
Mean (months±SD)	21.0 ± 7.9	22.3 ± 14.0	22.3 ± 13.7	N.S.
Range	6 - 36	4 - 84	4 - 84	
Resided in fluoridated area				
Yes	10 (21%)	61 (14%)	71(15%)	N.S.
No	38 (79%)	372 (86%)	410(85%)	

Results

Demography of study population (Table 3)

In the total of 481 subjects examined, 2148 permanent first and second molars were examined. Two hundred and nineteen teeth (10%) were excluded on the basis of unsuitable clinical or radiographic criteria, leaving a total of 1929 teeth for inclusion in the study. Of these, 1683 (87%) were permanent first molars (863 mandibular and 820 maxillary), and 246 (13%) permanent second molars (140 mandibular and 106 maxillary).

Details of the 481 subjects are shown in Table 3. There were 265 (55% boys), and 216 (45%) girls). The mean age ± standard deviation at the time of examination was 8.1 ± 2.2 years (range 5 to 12 years).

Of the 481 subjects, 118 (25%) had at least one medical condition noted on their medical history forms. The most commonly reported was asthma (54%), followed by allergies (20%), cardiovascular conditions (6%), and other, unspecified conditions (3%).

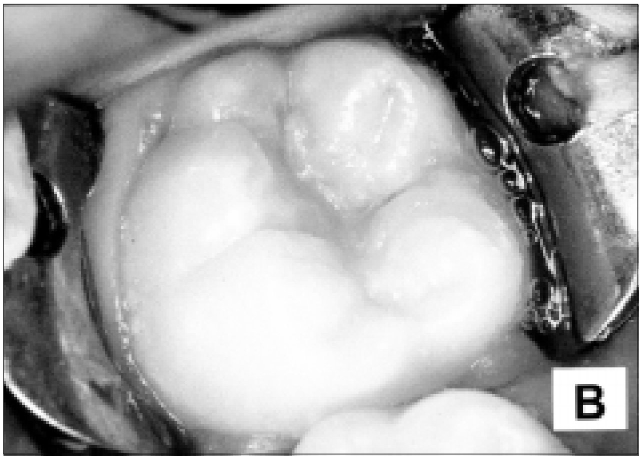

Fig 1B. Mandibular first permanent molar clinically scored as sound.

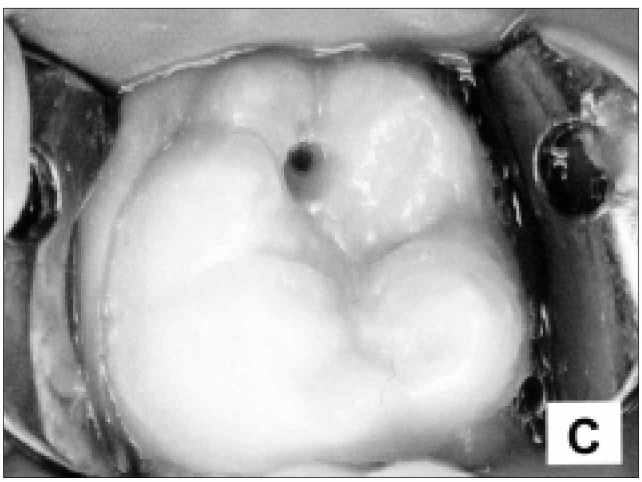

Fig 1C. Clinical appearance of the tooth at operative access.

Despite the lack of fluoride in Brisbane's water supply, only 21% of subjects had a positive history of fluoride supplementation. The majority of subjects were born in non-fluoridated areas, and the mean age at which fluoride toothpaste use begun (± standard deviation) was 22 ± 14 months (range 4 to 84 months).

As shown in Table 3, there were 48 subjects with at least one tooth with a dentin radiolucency beneath a clinically sound occlusal surface, giving an overall subject prevalence of 10% (95% CI: 7.5 % – 12.9%). There was no gender difference (males 11% vs. females 9%, $P>0.1$).

By comparison, of the 1929 teeth examined, only 72 exhibited a dentin radiolucency beneath a clinically sound occlusal surface, giving an overall tooth prevalence of 4% (Table 3). There was no gender difference in tooth prevalence (males 4.2% vs. females 3.1%, $P>0.1$). In addition, there were no statistical differences in the prevalence of occlusal dentin caries between those with and without medical conditions and fluoride exposure (fluoride supplementation, commencement of toothpaste use, residence in fluoridated area).

Correlation of clinical and radiographic assessments (Table 4)

The individual results of clinical assessment of the 1929 teeth were correlated against the results of radiographic assessment and are shown in Table 4.

Sensitivity and specificity of clinical examination (Table 5)

Of the 1833 teeth scored as "clinically sound" (score CO-C3), only 72 (4%) demonstrated a dentin radiolucency on bitewings (radiographic score R1-R3), and 1761 (96%) were scored as "radiographically sound" (RO). The sensitivity of the clinical examination was thus determined to be 0.96 (Table 5).

On the other hand, in the teeth clinically scored as showing dentin caries (clinical scores C4-C5), only 56/96 (58%) were found to have dentin radiolucencies on the bitewing radiographs (radiographic scores R1-R3). The specificity of the technique was determined to be 0.58 (Table 5).

Discussion

With increasing recognition today that occlusal caries now contributes to the majority of all new caries lesions in young permanent teeth,[1-3] accurate diagnosis of the caries status of the occlusal surface is of clinical significance in pediatric dentistry. However, in spite of the availability of various high-tech de-

Table 4. Cross Tabulation of Clinical and Radiographic Scores

	Clinical score• N (%)									
	Unsealed teeth						Sealed teeth			
Radiographic score• N (%)	C0	C1	C2	C3	C4	C5	F0	F1	F2	**Row Total** N *(%)*
R0	961 50%	207 11%	146 8%	50 3%	40 2%	0 0%	240 12%	157 8%	0 05	**1801** **93%**
R1	20 1%	9 0.5%	3 0.2%	3 0.2%	14 0.7%	19 1.0%	14 0.7%	16 0.8%	6 0.3%	**104** **5%**
R2	3 0.2%	0 0%	0 0%	0 0%	1 0.1%	9 0.5%	3 0.2%	1 0.1%	1 0.1%	**18** **1%**
R3	0 0%	0 0%	0 0%	0 0%	1 0.1%	5 0.3%	0 0%	0 0%	0 0%	**6** **1%**
Column Total N (%)	**984** **51%**	**216** **11%**	**149** **8%**	**53** **3%**	**56** **3%**	**33** **2%**	**257** **13%**	**174** **9%**	**7** **0.4%**	**1929** **100%**

•Refer to Table 1 for description of scores.

Table 5. Dentin Radiolucencies in Unsealed and Sealed Teeth Clinically Scored as Sound and in Teeth Scored as Having Dentin Caries*

	Radiolucency in occlusal dentin on bitewing radiographs(R1-R3)			
	Present		**Absent**	
	Teeth clinically scored as dentin caries (C4-C5)	***P*-value** *(carious vs sound)*	Teeth clinically scored as sound (C0)	***P*-value** *(carious vs sound)*
Unsealed molars	49/89 (55%)	P<0.001	1364/1402 (97%)	P<0.001
Sealed molars	7/7 (100%)	P<0.001	397/431 (92%)	P<0.001
Total	**56/96*** **(58%)**	**P<0.001**	**1761/1833**** **(96%)**	**P<0.001**

*The specificity of the clinical examination was determined to be 0.58.
**The sensitivity of the clinical examination was determined to be 0.96.

vices,[28,29] diagnosis of occlusal caries is still very much dependent on the use of the explorer and direct visual inspection. In this regard, the employment of appropriate clinical criteria to define various stages in the caries process may greatly improve diagnosis of occlusal caries status. The diagnosis of the early occlusal lesion, particularly in regard to whether the caries is limited to enamel or has involved dentin is important to differentiate those lesions which may be managed conservatively from those which require restoration.

In the present study we therefore tested a set of clinical criteria based on visual-tactile examination after thorough air-drying, to determine its ability to diagnose dentin lesions present on bitewing radiographs. The clinical criteria used were modified from those proposed by Ekstrand et al[30] who demonstrated their applications in in-vitro studies correlating with histology, as well as in a clinical study.[5] Using these modified criteria, we found the sensitivity of this technique for sound teeth was 0.96, that is, in 96% of teeth which were scored clinically as sound, the diagnosis matched the radiographic score of no dentin caries.

On the other hand, the specificity, or the ability of this technique to distinguish between sound and carious teeth, was only 0.58. This figure indicates that when occlusal surfaces were clinically scored as having dentin caries, only 58% were found to have a radiographic lesion. The other 42% of teeth which were clinically scored as having dentin caries, did not show a dentin radiolucency, demonstrating false positive findings. Thus the clinical technique may be overdiagnosing dentin caries, and this may be largely due to the inclusion of "stickiness during probing" (fissure score C4, Table 1) as dentin caries. This feature may not always be indicative of dentin caries, as other factors besides caries, such as probing pressure, the path of insertion and withdrawal of the explorer, the width of the explorer tip, and fissure anatomy can also cause "stickiness" of the explorer.[19]

Furthermore, early occlusal dentin lesions (fissure score C4, Table 1) do not always appear as distinct dentin radiolucencies on bitewing radiographs,[28,31] due to their relatively less demineralized state in comparison with more established lesions. Therefore, many early lesions in dentin may not be easily diagnosed from bitewing radiographs.

The nature of dentin radiolucencies beneath clinically sound occlusal surfaces has received much speculation. These lesions termed "occult" or "hidden" lesions, were thought to exist at prevalence rates of 3-50%.[10,12] Fluoride has previously provided a popular explanation for some large occult lesions, because it was thought that fluoride causes the enamel to remain hard and intact, so that caries continue undetected in the dentin.[14,33,34] However, it is now clear from the results of previous investigations,[35-37] that fluoride probably plays minimal role in the etiology of the dentin lesions which are not clinically detectable. In this regard, the present results confirm and extend previous studies in that fluoride exposure in the form of supplements, toothpaste, and water fluoridation did not influence the prevalence of dentin lesions that were not clinically detected.

According to Seow,[33] while the majority of occult lesions are probably the result of inadequate clinical diagnosis, a small proportion results from pre-eruptive intracoronal resorption of the teeth.[36-39] These pre-eruptive lesions become secondarily infected by cariogenic bacteria upon tooth eruption, so that they become clinically indistinguishable from caries. Others may erupt with a completely intact occlusal surface, giving an appearance similar to that shown in Figure 1. In this regard, it may be speculated that the small percentage (4%) of dentin lesions not detectable by clinical examination may have their origins as preeruptive intracoronal resorption lesions.

Regarding the management of radiographic dentin lesions beneath clinically sound occlusal surfaces, there appears to be a consensus opinion that once an occlusal lesion is visible radiographically it should be restored[15,16] with either adhesive materials such as glass ionomer cements and composite resins or amalgam. It is likely that once an occlusal lesion is visible on a radiograph, the demineralization has already extended to at least the middle third of dentin, and there is also a significant rise in the number of recoverable bacteria in the dentin when a lesion is radiographically visible compared to one that is not.[42]

An alternative procedure is the ultraconservative, so-called "cariostatic" restoration in which occlusal caries is left sealed within the restoration.[43] Although this technique has demonstrated high efficacy rates,[44] it is well established that success of such restorations highly depends on the its margin seal. Hence frequent monitoring of the clinical integrity of such restorations is warranted.

Conclusions

1. Clinical examination of cleaned and dried sealed and unsealed teeth has a sensitivity of 0.96 and a specificity of 0.58 in the detection of dentin radiolucencies in bitewing radiographs.
2. Dentin radiolucencies beneath clinically sound occlusal surfaces were not significantly associated with gender, medical conditions, and fluoride exposure.

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Abstracts of the Scientific Literature

Influence of dentin conditioning on Class II restorations

Microleakage and recurrent caries at the cervical wall of the interproximal box of large Class II composite resin restorations are frequently observed in pediatric patients. This might be due to limited area of enamel available for bonding, dentin tubule orientation, and increased risk for saliva/blood contamination. The objective of this *in vitro* study was to evaluate the influence of contamination of the cervical wall of Class II cavity preparations on the marginal adaptation and microleakage of sandwich restorations using either a resin-modified glass ionomer (Vitremer + Z100) or a compomer (F2000 + Z100) compared to composite restorations (Z100). The authors found that both Vitremer/Z100 and F2000/Z100 sandwich restorations showed better marginal adaptation than Z100 only restorations with all pretreatments tested. Microleakage could not be eliminated consistently with the sandwich technique. However, sandwich restorations (Vitremer/Z100 or F2000/Z100) were less sensitive to contamination with saliva and blood than composite resin (Z100) restorations.

Comments: This study demonstrates that sandwich Class II restorations have improved marginal integrity compared to composite resin restorations, and might be less sensitive to contamination by saliva and blood. **JN**

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Influence of dentin conditioning and contamination on the marginal integrity of sandwich Class II restorations. Dietrich T, Kraemer M, Lösche GM, Wernecke KD, Roulet JF. Oper Dent 25: 401-410; 2000.

49 references

Occlusal Contacts in the Primary Dentition

Very little is known regarding the functioning occlusion in the primary dentition. Numerous attempts have been made to establish the location of occlusal contacts between upper and lower teeth at intercuspal position in adults. However, tracking contacts during functional movements is extremely difficult. In adults, non-working occlusal contacts are thought to be initiating factors for parafunctional activity. In this study, the authors developed a measurement system that combined a tracking system for mandibular movements with a three dimensional system digitizer for tooth shape. They used this system to detect occlusal contacts during lateral excursions in children aged 4-6 years. Estimated occlusal contact area of the second primary molar on the nonworking side was 0.8mm^2, in contrast to 2.0 mm^2 on the working side at 3.0 mm of movement of the lower incisors. All children had some occlusal contacts on the non-working side during the first part of lateral excursion.

Comments: A clever method has been developed to investigate occlusal contacts during function. Somewhat surprisingly, the authors clearly demonstrate the presence of occlusal contact on the non-working side during function. Surprisingly little is known regarding the function of the masticatory system in the primary dentition. **CH**

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Occlusal contacts during Lateral Excursions in Children with Primary Dentition. Okamoto A , Hayasaki H, Nishijima N, Iwase Y, Yamasaki Y and Nakata M. J Dent Res 2000. 79(11):1890-1895.