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Detection of Approximal Caries Lesions in Adults: A Cross-sectional Study

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Clinical Relevance

Direct visual inspection following temporary tooth separation of approximal lesions that reach the D1-D2 of dentin may contribute to a better decision making about restorative treatment.

SUMMARY

Detection and management of posterior approximal caries lesions are still problematic. Inspection of approximal surfaces is challenging, and bitewing radiographs are used when direct vision is not possible. Unfortunately, there is no definite radiographic appearance to identify lesion cavitation with absolute certainty. Many lesions detected radiographically within the outer half of dentin are not cavitated, often resulting in unnecessary restorative treatment. Our study compared radiographic depth of approximal caries lesions with presence of cavitation in adults using visual inspection following temporary tooth separation (TTS). We conducted this observational descriptive cross-sectional study at two dental schools in two cities in Chile. Clinicians were unaware of radiographic depths of lesions and examined 147 participants (57.3% female and 42.7% male) following TTS. Using the common classification system that consists of E0 (no lesion), E1 (lesion within the outer half of enamel), E2 (lesion within the inner half of enamel), D1 (lesion within the outer third of dentin), D2 (lesion within the middle third of

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DOI: 10.2341/17-314-C

dentin), and D3 (lesion within the inner third of dentin), a trained dentist evaluated all the processed films. Cavitation was detected in only three sites (0.22%) within the E0 category, seven sites (3.41%) in E1, five sites (14.8%) in E2, four sites (14.8%) in D1, six sites (50%) in D2, and eight sites (61.5%) in D3. Considering that restorative treatment should be indicated strictly for cavitated lesions, our findings support indication for restorative treatment for D3 lesions and the rationale for TTS for D1-D2 caries lesions to allow direct visual inspection to determine whether there is surface cavitation.

INTRODUCTION

The detection and management of approximal caries lesions in areas of posterior tooth contact are still problematic for clinicians. Direct vision of approximal surfaces is challenging; hence, radiographic examination of these surfaces is fundamental.[1] Bitewing radiography is used to evaluate approximal lesions that cannot be readily identified clinically. This also allows estimating lesion depth and its relationship with the dental pulp and permits monitoring lesion progression. These are essential aspects in the decision-making process when considering treatment.[2]

Unfortunately, there is no definite radiographic appearance to identify the presence of cavitated lesions with absolute certainty.[1,3] Nevertheless, bitewing radiographs are still widely used and present a far better alternative when compared with clinical examination without radiographic examination.[4] There is great variation across studies between radiographic images and the presence of cavitation. Many lesions detected radiographically within the outer half of dentin are not cavitated.[5-7] Also, there is a great deal of variation from one clinician to another in the decision-making process regarding treatment of approximal caries lesions, which may often result in invasive treatment at an early stage.[8] Restorative treatment of approximal surfaces leads to the removal of large areas of sound enamel, causing structural damage to the tooth through loss of marginal ridges and initiating a re-restorative cycle for the tooth. There is also a potential risk of further damage to adjacent surfaces.[9,10] With all this in mind, it is relevant to determine the relationship between the clinical status of caries lesions, their level of radiographic radiolucency, and their correlation in terms of cavitation. This would improve the indications for noninvasive as well as restorative treatment for approximal caries lesions and allow making the right therapeutic recommendations.

The aim of this study was to compare the radiographic depth of approximal caries lesions with the presence of cavitation by means of visual inspection following temporary tooth separation (TTS) in adult patients.

METHODS AND MATERIALS

This observational descriptive cross-sectional *in vivo* study was performed as a diagnostic test on previously consented patients at the dental clinics of the Faculty of Dentistry (University of Chile, Santiago, Chile) and the Dental Institute (Austral University, Valdivia, Chile). Both institutions openly provide dental care within the community as part of their academic activities.

All participants were informed and gave their consent to take part in this study in accordance with the Declaration of Helsinki. Participants signed an informed consent form previously approved by the relevant ethics committees.

The following surfaces of permanent teeth were included in this study:

- Mesial surfaces of second premolars, first molars, and second molars
- Distal surfaces of first premolars, second premolars, and first molars

The following surfaces were excluded:

- Approximal surfaces with no approximal contact area or without an adjacent tooth
- Restored approximal surfaces or those adjacent to restored approximal surfaces
- Dental or maxillofacial anomalies precluding examination of interproximal spaces

A trained operator took conventional bitewing radiographs as part of the radiographic examination using double films (D57, Ultraspeed, fine grain, Kodak, Rochester, USA). The exposure of all films was standardized. Intraoral radiograph holding devices were used to keep intraoral films in place and help position the X-ray tube. These devices allow standardizing the angulation of the X-ray beam and facilitate taking reproducible radiographic views. The exposure time and settings were the same for both premolar and molar teeth: 0.4 seconds, 70 kV, and 8 mA. The same operator who took the radiographs processed the films using an automatic

developer (Periomat Plus 1307/1308, Dürr, Bietigheim-Bissingen, Germany) according to the manufacturer's instructions. Using the common classification system that consists of E0 (no lesion), E1 (lesion within the outer half of enamel), E2 (lesion within the inner half of enamel), D1 (lesion within the outer third of dentin), D2 (lesion within the middle third of dentin), and D3 (lesion within the inner third of dentin), a trained dentist evaluated all the processed films.[11] Radiographs were assessed using a light box under optimal conditions.

A dental radiologist collated and recorded radiographic data in a *pro forma* form, subsequently highlighting the proximal surfaces of teeth that conformed to the inclusion criteria of this study, recording in writing the corresponding code (E0, E1, E2, D1, D2, D3) for each approximal surface. Clinical operators were unaware of the radiographic depths of caries lesions. Coded data from these forms were stored in a computer file (Excel for Windows) and later analyzed using data analysis software (Stata 11.0, Stata Corp, Texas, USA). A descriptive analysis of data was performed. The percentage of sites according to proximal caries lesion depth on bitewing radiographs was calculated.

Participants underwent TTS with orthodontic elastic bands (AlastiK radiopaque separators, 3M Unittek, St. Paul, Minnesota ,USA) in premolars and molars for three days[12] according to the inclusion criteria. Following TTS, interproximal spaces were cleaned after the removal of the separator using water spray and dental floss (Oral-B, Santiago, Chile). Teeth were clinically examined immediately after cleaning using direct vision in order to check for the presence or absence of surface cavitation. Tactile examination was also performed using the World Health Organization probe developed for the *Community Periodontal Index of Treatment Need* method. Suitably trained clinicians who had been previously calibrated in the detection of dental surface cavitation visually examined all temporarily separated approximal surfaces. For the purpose of this study, presence of cavitation was established as a break in continuity in enamel detectable on visual examination. Examinations were performed using dental chairs with relative isolation (cotton swabs and saliva ejector), using dental mirrors, three-in-one syringes to dry the teeth, and artificial light. No dental loupes were used. The presence and proportion of approximal caries lesions following visual inspection and their relationship with radiographic depth were calculated. The percentage of sites with cavitated approximal lesions according to visual inspection was also calculated.

RESULTS

The number of approximal surfaces included in this study according to the inclusion criteria was 1937. Two hundred and twenty approximal sites (11.4%) were excluded from the study: 15.7% in Santiago and 7.2% in Valdivia. Reasons for exclusion from the study included patients who abandoned dental treatment or those for whom full data were not obtained, for example, due to lack of compliance, loss or self-removal of the orthodontic elastics, or presence of sites where clinical examination proved inaccessible. Thus, the total number of approximal surfaces examined clinically was 1717.

The number of participants was 146 with an average of 11.7 (SD 6.7) approximal surfaces evaluated and an average age of 25.2 (SD 8.8) years; 57.3% of participants were female, and 42.7% were male. Within our sample, 75.2% came from the dental clinic at Austral University and 24.8% from the dental clinic at the University of Chile.

Depth of Approximal Caries Lesions Detected on Bitewing Radiographs

Of the total number of approximal surfaces evaluated by means of bitewing radiography, 70.8% corresponded to healthy sites (E0), whereas 19.7% displayed radiographic evidence of caries and lesion presence of varying depths. Visual inspection on clinical examination of approximal surfaces post-TTS revealed 33 sites with cavitated caries lesions. When relating the presence of identified cavitated approximal caries lesions according to visual inspection to recorded radiographic depths, cavitation was detected in only three sites (0.22%) within the E0 category, seven sites (3.41%) in E1, five sites (14.8%) in E2, four sites (14.8%) in D1, six sites (50%) in D2, and eight sites (61.5%) in D3 (see Table 1). We observed a high proportion of lesions that were radiographically into dentin (D1-D3) and that were deemed noncavitated caries lesions; 34 of 52 (65.4%) lesions identified as affecting dentin by radiograph were noncavitated lesions.

DISCUSSION

Detection of dental caries using bitewing radiographs provides information about the presence and depth of approximal lesions. However, the use of radiography presents limited sensitivity in the detection of cavitation.[13,14] Hence, the use of elastic

Table 1: *Number of Approximal Cavitated and Noncavitated Caries Lesions on Direct Visual Inspection and Their Distribution According to Different Categories of Radiographic Depth*

Direct Visual Inspection	Categories of Caries Lesion Severity on Radiographic Diagnosis (n [%])						
	E0	E1	E2	D1	D2	D3	Total
Noncavitated	1375 (99.8%)	198 (96.6%)	77 (93.9%)	23 (85.2%)	6 (50%)	5 (38.5%)	1684 (98.1%)
Cavitated	3 (0.2%)	7 (3.4%)	5 (6.1%)	4 (14.8%)	6 (50%)	8 (61.5%)	33 (1.9%)
Total	1378	205	82	27	12	13	1717

Abbreviations: E0, no lesion; E1, lesion within the outer half of enamel; E2, lesion within the inner half of enamel; D1, lesion within the outer third of dentin; D2, lesion within the middle third of dentin; D3, lesion within the inner third of dentin.

bands has been proposed in order to achieve interproximal separation and allow visual inspection of interproximal sites. This reversible and low-cost method eliminates interproximal contact points between adjacent teeth and thus improves the performance of conventional visual inspection.[15,16] The aim of this *in vivo* study was to compare the radiographic depths of approximal caries lesions with the presence of cavitation by means of direct visual inspection of surfaces in molar and premolar permanent teeth in adults following a period of TTS to determine the relationship between the stage of clinical progression of caries lesions and the level of radiolucency observed in the radiographs taken.

Our sample of 1717 surfaces was representative of the Chilean adult population in terms of gender and came from two cities engaged in tap water artificial fluoridation programs (Santiago: 0.62 ppm fluoride; Valdivia: 0.939 ppm fluoride).[17,18] Reasons for exclusion of approximal surfaces from the study included incomplete recording of data in situations where inadequate tooth separation was attained due to participant withdrawal from the study or loss of elastics, resulting in an 88.6% of retention rate of surfaces examined. In order to address this issue, 10% oversampling was built into the study design. There are no reasons to think either that this loss rate could have resulted in a source of bias, which in turn could affect the results, or that there were different characteristics between approximal sites that were lost and those that remained in the study. As the radiographic depth of caries lesions increased, we observed an increase in the proportion of approximal lesion cavitation.

The majority of approximal caries lesions were not cavitated. Preventive treatment is therefore indicated in these cases. The proportion of approximal cavitated lesions detected by visual inspection after TTS is directly related to the radiographic depth. As radiographic depth increased, so did the number of cavitated sites (Table 1), which concurs with Nielsen and others;[13] who emphasized the relationship between caries lesion depth and the probability of cavitation presence. It follows that the probability of cavitation within an approximal enamel lesion is low, and it would be incorrect to assume all radiolucent lesions in dentin to be cavitated.[3,19] According to our results, there was a small number of cavitated sites within the E0 category. This might have been due to limitations inherent to the radiographic technique used in the detection of interproximal caries lesions in our study.

Since the 1970s, several clinical studies have been developed with the aim to relate radiographic appearance of caries lesions to the probability of cavitation presence. Methodologies used in other studies differ from the one used in our study. Some authors evaluated approximal surfaces using study casts following TTS and impression making.[20-22] Other studies looked at approximal surfaces at the time of tooth extraction.[23] Others evaluated approximal surfaces at the cavity preparation stage, which raises the question of whether operator error may have resulted in unintended rotary instrument contact against approximal surfaces causing accidental cavitation, thus altering their results.[8,19,24]

When comparing our study with other clinical studies of similar methodology, it is possible to see our results agree with those of Pitts and Rimmer[3] and Hintze and others[6] given that similar percentages of cavitated surfaces were found radiographically in categories R0, R1, R2, R3, and R4.[5,25,26] We also looked at percentages of cavitated surfaces in relation to radiographic depths comparable with the studies mentioned previously. Our study determined a lower proportion of cavitated surfaces in stages D1 and D2 compared with those earlier reported by others. The percentage of cavitated surfaces detected in this study proved lower than those reported by other studies.[5,23,25,26] Reasons for these differences might include the relatively younger age-group within our study and the exposure of participants to fluoridated tap water. With regard to the work of Coutinho and daRocha

Costa, it was not possible to draw comparisons because their study used different categories of radiographic depth and also evaluated approximal lesions of deciduous molars.[27] It is worth highlighting that except for histological sectioning, which is considered to be the true gold standard for detecting demineralization of dental tissues, no other available method for caries detection is able to attain such results.[3]

Our results are clinically relevant, as they show that the probability for an approximal enamel lesion to be cavitated (E1 or E2) is very low. Hence, the management of these lesions should be based on plaque control, application of remineralization therapies, and timely clinical as well as radiographic monitoring. Results also confirm once again the importance of preventive and noninvasive treatment. Most approximal caries lesions in posterior permanent teeth were not cavitated and therefore do not require restorative treatment, especially at the D1 level. Our results support current evidence-based clinical recommendations to restore lesions only when cavitation is present. Postponing operative intervention avoids committing teeth to an endless restorative cycle and generates biological benefits for patients, enabling them to keep their teeth for longer throughout their lives.[28] Historically, the use of dental services in public health has not created great benefits in terms of a decrease in caries incidence. A small contribution (3%) of dental services to the decline of the disease has been reported, while a 65% decrease has been associated with socioeconomic factors and access to fluoride.[29] The role of dentistry in decreasing the prevalence and incidence of dental caries should focus on early lesion prevention and remineralization in order to delay any operative intervention for as long as possible. Approximal restorative treatment should be performed only in the presence of cavitation, as in those circumstances biofilm removal within the cavity would not be possible by otherwise conventional means (brushing and flossing or other interproximal cleaning), thus posing a higher risk of lesion progression. TTS is an adjunct to clinical and radiographic detection of caries lesions, particularly when lesions are confined to dentin at the D2 and D3 levels given the probability of cavitation and therefore the need for restorative treatment. Hence, using TTS in lesions confined to dentin (D2-D3) should assist clinicians in determining the presence of surface cavitation and helping to establish the optimal timing for restorative treatment when required.

As far as we know, this is the first study in adults in Latin America that correlates the presence of approximal caries lesions detected visually and radiographically to the presence of cavitation in adult patients. Our study builds on prior research in this field.

CONCLUSIONS

In this study, only 14.8% of lesions in category D1 were cavitated on clinical inspection, and in category D2 the proportion was 50%, while in D3 the proportion was 61.5%. Taking into consideration that restorative treatment should be indicated strictly for cavitated lesions, our clinical recommendations based on our results are the following:

- D3 radiographic caries lesions are more likely to be cavitated; therefore, restorative treatment is indicated.
- It is highly recommended that D1 and D2 radiographic caries lesions undergo TTS in order to increase diagnostic accuracy and decide whether to perform restorative treatment.

Acknowledgements

This study was funded by CONICYT-FONIS SA13I20068 (Government of Chile) and approved by the Ethics Committees of the Faculty of Dentistry at the University of Chile and the Faculty of Medicine at the Austral University of Chile (approval number 2013/45 November 2013).

Conflict of Interest

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

(Accepted 21 December 2018)

REFERENCES

1. Pitts NB & Longbottom C (1987) Temporary tooth separation with special reference to the diagnosis and preventive management of equivocal approximal carious lesions *Quintessence International* **18(8)** 563-573.
2. Pitts NB & Kidd EA (1992) Some of the factors to be considered in the prescription and timing of bitewing radiography in the diagnosis and management of dental caries *Journal of Dentistry* **20(2)** 74-84.
3. Pitts NB & Rimmer PA (1992) An in vivo comparison of radiographic and directly assessed clinical caries status of posterior approximal surfaces in primary and permanent teeth *Caries Research* **26(2)** 146-152.
4. Kidd EA & Pitts NB (1990) A reappraisal of the value of the bitewing radiograph in the diagnosis of posterior approximal caries *British Dental Journal* **169(7)** 195-200.
5. Akpata ES, Farid MR, al-Saif K, & Roberts EA (1996) Cavitation at radiolucent areas on proximal surfaces of posterior teeth *Caries Research* **30(5)** 313-316.

6. Hintze H, Wenzel A, & Danielsen B (1999) Behaviour of approximal carious lesions assessed by clinical examination after tooth separation and radiography: A 2.5-year longitudinal study in young adults *Caries Research* **33(6)** 415-422.
7. Meyer-Lueckel H, Fejerskov O, & Paris (2009) [Novel treatment possibilities for proximal caries] *Schweiz Monatsschrift Zahnmed* **119(5)** 454-461.
8. Mejàre I & Malmgren B (1986) Clinical and radiographic appearance of proximal carious lesions at the time of operative treatment in young permanent teeth *Scandinavian Journal of Dental Research* **94(1)** 19-26.
9. Medeiros VA & Seddon RP (2000) Iatrogenic damage to approximal surfaces in contact with class II restorations *Journal of Dentistry* **28(2)** 103-110.
10. Phark J-H, Duarte S, Meyer-Lueckel H, & Paris S (2009) Caries infiltration with resins: A novel treatment option for interproximal caries *Compendium of Continuing Education in Dentistry* **30(Special Issue 3)** 13-17.
11. Anusavice K (2005) Present and future approaches for the control of caries *Journal of Dental Education* **69(5)** 538-854.
12. Nyvad B, Fejerskov O, & Baelum V (2008) Visual-tactile caries diagnosis In Fejerskov O, Kidd E (eds) *Dental Caries: The Disease and Its Clinical Management* **2nd edition** Blackwell, Oxford 49-68.
13. Nielsen LL, Hoernoe M, & Wenzel A (1996) Radiographic detection of cavitation in approximal surfaces of primary teeth using a digital storage phosphor system and conventional film, and the relationship between cavitation and radiographic lesion depth: An in vitro study *International Journal of Paediatric Dentistry* **6(3)** 167-172.
14. Schwendicke F, Tzschoppe M, & Paris S (2015) Radiographic caries detection: A systematic review and meta-analysis *Journal of Dentistry* **43(8)** 924-933.
15. Mialhe FL, Pereira AC, Pardi V, & de Castro Meneghim M (2003) Comparison of three methods for detection of carious lesions in proximal surfaces versus direct visual examination after tooth separation *Journal of Clinical Pediatric Dentistry* **28(1)** 59-62.
16. Rimmer PA & Pitts NB (1990) Temporary elective tooth separation as a diagnostic aid in general dental practice *British Dental Journal* **169(3-4)** 87-92.
17. Guerrero S, Cisternas P, González S, & Uauy R (1983) [Fluoride content of natural waters in Chile and recommendations for its supplementation] *Revista Chilena de Pediatríca* **54(3)** 162-166.
18. Superintendencia de Salud C (2015) Valores promedios informados para el parámetro flúor por los servicios de agua potable del país; Retrieved online October, 15, 2016 from: http://www.siss.gob.cl/577/w3-propertyvalue-3525.html
19. Bille J & Thylstrup A (1982) Radiographic diagnosis and clinical tissue changes in relation to treatment of approximal carious lesions *Caries Research* **16(1)** 1-6.
20. Lunder N & von der Fehr FR (1996) Approximal cavitation related to bite-wing image and caries activity in adolescents *Caries Research* **30(2)** 143-147.
21. Ratledge DK, Kidd EA, & Beighton D (2001) A clinical and microbiological study of approximal carious lesions. Part 1: The relationship between cavitation, radiographic lesion depth, the site-specific gingival index and the level of infection of the dentin *Caries Research* **35(1)** 3-7.
22. Seddon RP (1989) The detection of cavitation in carious approximal surfaces in vivo by tooth separation, impression and scanning electron microscopy *Journal of Dentistry* **17(3)** 117-120.
23. Mejàre I, Gröndahl HG, Carlstedt K, Grever AC, & Ottosson E (1985) Accuracy at radiography and probing for the diagnosis of proximal caries *Scandinavian Journal of Dental Research* **93(2)** 178-184.
24. Thylstrup A, Bille J, & Qvist V (1986) Radiographic and observed tissue changes in approximal carious lesions at the time of operative treatment *Caries Research* **20(1)** 75-84.
25. De Araujo FB, Rosito DB, Toigo E, & dos Santos CK (1992) Diagnosis of approximal caries: Radiographic versus clinical examination using tooth separation *American Journal of Dentistry* **5(5)** 245-248.
26. Rugg-Gunn AJ (1972) Approximal carious lesions: A comparison of the radiological and clinical appearances *British Dental Journal* **133(11)** 481-484.
27. Coutinho TC & daRocha Costa C (2014) An in vivo comparison of radiographic and clinical examination with separation for assessment of approximal caries in primary teeth *European Journal of Paediatric Dentistry* **15(4)** 371-374.
28. Elderton RJ (1990) Clinical studies concerning re-restoration of teeth *Advances in Dental Research* **4** 4-9.
29. Nadanovsky P & Sheiham A (1995) Relative contribution of dental services to the changes in caries levels of 12-year-old children in 18 industrialized countries in the 1970s and early 1980s *Community Dentistry and Oral Epidemiology* **23(6)** 331-339.