Acta Odontologica Scandinavica, 2005; 63: 308–313

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ORIGINAL ARTICLE

Relationships between occlusal or free-smooth and approximal caries in mixed dentition

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Abstract

This cross-sectional study aimed to examine the relationships between free-smooth or occlusal surfaces and approximal caries in 104 schoolchildren between 6 and 8 years of age. Caries diagnosis was clinically and radiographically assessed, and white spot lesions, evident caries lesions or restorations, as well as radiolucence in enamel were considered to be caries. In the studied subjects, the correlations were analyzed in the 1st primary molars (Ds), the 2nd primary molars (Es), the 1st permanent molars (6s), and all molars. The data were statistically analyzed by chi-square test. Significant correlations between occlusal surface caries and approximal surface lesions were observed in Ds and Es teeth and in all molars, but not for 1st permanent molars. For free-smooth surface, these correlations were significant only for Es and all molars. Sensitivity and specificity for occlusal surface as an indicator of approximal caries in the same tooth type ranged from 73% to 83% and 51% to 58%, respectively. Similarly, for free-smooth surface the values varied from 22% to 60% and 57% to 90%, respectively. Sensitivity and specificity for occlusal surface caries in identifying subjects with approximal caries were 78% and 70%, respectively; for free-smooth surface, the corresponding values were 59% and 65%, respectively. The results suggest that visually detected caries lesions are indicative of approximal caries. Thus, if a certain risk limit is defined and the corresponding number of caries lesions in different surfaces is reached, the risk is above the threshold and could be a practical guideline on the need for radiography in this age group of patients with "moderate caries experience".

Key Words: *Caries prediction, dental caries, radiography*

Introduction

Treatment of advanced approximal caries lesions may cause great loss of sound dental tissue, while small lesions have the potential to remineralize with the timely application of preventive measures. Attempts have been made to develop and improve diagnostic methods that enable an early diagnosis of approximal lesions undetectable by visual inspection [1]. The usefulness of conventional bitewing radiography in detecting approximal lesions has been validated and this method remains the most common diagnostic aid, because it reveals lesions inaccessible to direct or tactile examination [2]. Additionally, conventional radiography is still a significant and accurate method for detecting approximal caries [3], the correct caries status being underestimated when clinical examination only is performed without bitewing radiographs [4]. However, concern related to effects of using ionizing radiation, mainly in young children, demands that radiographic exposure be limited [5]. Despite this method being recommended as an adjunct to clinical observations, decisions to supplement clinical examinations with bitewing radiographs are arbitrary [6–10]. Studies on caries risk assessment have shown that past caries experience variables compared to other variables have a relatively strong association with caries increment, and that caries experience is the best predictor of caries in children with mixed dentition [11–15]. Caries experience has thus been

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(Received 16 November 2004; accepted 8 June 2005)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.1080/00016350500206702

recommended as an indication of the need for supplementary radiographs [16,17]. Therefore, decisions to produce bitewing radiographs are frequently based on clinical observations [18], but this practice is supported by little research evidence. Studies point out that free-smooth surface caries experience has a positive correlation with approximal caries experience [5,19]. Furthermore, the frequency of caries on the approximal surfaces of the 1st and 2nd primary molars is higher when occlusal caries are present [20]. This being so, clinical observation of free-smooth or occlusal surfaces caries of molars in mixed dentition could be a predictor of the presence of approximal caries. However, no studies have been found in the literature determining whether or not free-smooth or occlusal surfaces caries in mixed dentition relates to the caries prevalence on approximal surfaces. This correlation is relevant from a clinical point of view, i.e. for scheduling appointments and radiography. This cross-sectional study therefore aimed at determining whether, in cases that show no clinical evidence of approximal caries, free-smooth or occlusal surface caries can predict the presence of radiographically detected approximal caries, thereby helping to make decisions with regard to supplementary clinical examinations.

Material and methods

Sample

A cross-sectional study design was used with subjects recruited as a convenience sample of children attending 17 public schools in Piracicaba, State of São Paulo, Brazil. Permission to carry out the research was obtained and the children's parents signed written informed consent (Resolution no. 196 of the National Health Council, Health Ministry, Braslia, DF, 10/03/1996).

Initially, 183 children who were participating in a dental assistance program at the State University of Campinas, Faculty of Dentistry of Piracicaba were examined, and those who had at least 6 out of 12 posterior teeth (1st and 2nd primary molars and 1st permanent molar) were selected. In addition, all the selected children had at least 50% of the maximum number of teeth from each type. Thus, 110 children were enrolled in the study. However, six of the children were excluded owing to the impossibility of performing an accurate radiographic diagnosis. The final sample comprised 104 boys and girls aged between 6 and 8 years (mean and median ages were 7.2 and 7 years, respectively) from the same socio-economic background.

The DFT and dft means were 2.12 and 5.04, respectively, representing a sample with moderate caries prevalence. The fluoride content of water was 0.7 mg/l. The parallel clinical and radiographic examinations for caries were conducted from March to May, 1995.

Examination conditions

Visual dental examinations were carried out by one of the authors (R.C.R.P.), who was previously calibrated by a benchmark examiner. The benchmark examiner, a dentist who routinely uses the World Health Organization criteria for examinations [21], had been previously trained and calibrated in the diagnosis of non-cavited carious lesions. Theoretical discussions using clinical photographic slides were held to instruct the examiner on the use of the criteria and the examination method, including explanations about the examinations for active non-cavited carious lesions. The entire time spent on the calibration process (theoretical discussions, training, and calibration exercises) was 20 h. The child examined sat in a dental chair and all teeth were dried with compressed air before being assessed. Clinical diagnoses were performed using a uniform source of light provided by a conventional operating dental light, a plane mouth mirror, and an explorer to remove remaining plaque. With the aid of a film holder (Kodak Ektaspeed plus Film 31×41 mm; Kodak, Rochester, New York, USA), two bitewings were taken for the radiographic diagnosis, one on each side of the mouth. The recommendation for radiographs was that it should capture an image of the tooth crowns from the distal surface of the canine to the distal surface of the posterior erupted molar. Radiographic examinations and diagnoses were performed by one of the authors (J.C.C.G.) experienced in radiological diagnosis. The examiner was also calibrated through theoretical discussions and radiographic image slides. The radiographs were processed under standardized conditions and the diagnosis was performed without reference to the clinical records. In order to apply the diagnostic criteria, the outer surface of each approximal surface had to be completely visible on the radiograph. If there was overlap or a non-visible approximal surface occurred and it was not possible to take a new radiograph, the child was eliminated.

Diagnostic criteria

For clinical examination, a surface was considered carious if visual impressions of caries (including white spot lesions) were noted, or if the surface was filled even when no sign of another lesion was found. Among carious or filled surfaces, the percentage of filled surfaces was 42.30%. For radiographic examination, a surface was considered carious if there was any radiolucence into the enamel or dentin, or if the surface was filled. Missing surfaces were not counted because of aberrant results caused by normal exfoliation. The bitewing radiographs were examined with an X-ray desk viewer without magnification. To determine intra-examiner agreement on a site basis, Kappa values were computed as described by Fleiss et al. (22). The Kappa coefficients were 0.86 and 0.88 for the clinical and radiographic examinations, respectively. To assess

Table I. Cut-off values for considering subjects as "positive" for caries presence in each surface and tooth type

Tooth type	Cut-off values		
	Approximal (mean DFS)	Occlusal (mean DFS)	Free-smooth (mean DFS)
6	⩾1	⩾2	⩾1
E	⩾1	⩾2	⩾1
D	⩾2	⩾1	⩾1
All molars	⩾3	⩾5	⩾2

the value of clinically detectable caries as a predictor of approximal lesions in different tooth types and in all posterior teeth, the children were dichotomized into positive or negative for caries presence based on the mean DFS score found in the population for each surface. Thus, the children who presented a mean DFS equal to or higher than that found for the total population were coded as positive, while the others were coded as negative (5). The cut-off values for each surface used for classifying the subjects as positive are given in Table I. The teeth considered in this study were the 1st primary molars (Ds), the 2nd primary molars (Es), and the 1st permanent molars (6s).

Statistical analysis

The following indexes were calculated for each child and for the population: dft and DFT, dfs and DFS.

For statistical analysis, indices of sensitivity, specificity, positive and negative prediction values, as well as the percentage of correct classification for occlusal and buccal-lingual caries as predictor of approximal caries, were calculated for each tooth type and for posterior teeth using the subject as the unit of analysis with a 2×2 model table and appropriate formulas (Table II). In this study, the correct classification percentage is equal to the total number of correctly classified children divided by the total number of children or teeth [23]. The data were processed using Epi-Info software version 5.01 and analyzed using the EPIBUCO program. The data were carefully entered in the computer and the input into the program was checked twice. In order to evaluate the significance of the association between caries prevalence in occlusal or free-smooth surfaces and approximal caries prevalence, the Yates corrected chi-squared test was used. The level of statistical significance was set at 0.05. In addition, as a measure of risk, odds ratios (OR) and their 95% confidence intervals (CI) were computed.

Table II. Model for determining predictive power of occlusal or free-smooth surface for approximal caries presence

Occlusal or free-smooth surface caries	Approximal caries	
	Positive	Negative
Positive	True positive	False positive
Negative	False negative	True negative

Table III. Teeth examined and percentage of carious or filled teeth

Arch and tooth	Maxilla		Mandible	
	n	Carious or filled %	*n*	Carious or filled %
6	203	49.2	204	48.0
E	202	56.0	200	59.0
D	191	31.9	186	20.9

Results

The number of teeth examined and the percentage of carious or filled surfaces are given in Table III. The prevalence of caries was higher in the Es teeth than in the others. For Ds teeth, a greater percentage of maxillary than mandibular teeth were carious or filled.

Table IV gives caries prevalence in occlusal and approximal surfaces as well as sensitivity, specificity, percentage of correct classification, positive and negative predictive values for caries presence in the approximal surfaces considering caries prevalence in occlusal surfaces. The same information with regard to free-smooth surfaces is presented in Table V. These values were determined for any one of the posterior tooth types and for all posterior teeth (subjects). The proportion of teeth, in the same subject, with both approximal and occlusal caries ranged from 73% to 83% (sensitivity), while this proportion with both approximal and buccal-lingual caries ranged from 22% to 60% (sensitivity). Up to 70% of the children presenting posterior teeth with no approximal caries had clinically sound occlusal surfaces (specificity). When the caries experience in occlusal surface was used to predict caries presence in approximal surfaces of the same tooth type, the study found an overall sensitivity of 83% for 6s and an overall specificity of 58% for Es (Table IV). When the caries experience in free-smooth surfaces was used, the results showed an overall sensitivity of 60% for Es and an overall specificity of 90% for Ds (Table V). The positive predictive value decreased when the approximal caries prevalence was low, even for high sensitivity or specificity values. Analyzing the different tooth types in each subject, the highest percentage of correct classification (72%) was found for occlusal caries on 2nd primary molars. When all posterior teeth were analyzed, the sensitivity and specificity values for occlusal surfaces were 78% and 70%, respectively, and 59% and 65% for buccal-lingual surfaces. Moreover, the highest percentage of correct classification (75%) was found when occlusal surface status was used as caries predictor for approximal caries.

Another way of determining the predictive value was by comparing the odds ratio values according to the caries status of different tooth surfaces and subjects in mixed dentition. As indicated in Tables VI and VII, when clinically detectable occlusal or free-smooth caries in 1st permanent molars was analyzed, a

Table IV. Caries prevalence on occlusal and approximal surfaces, sensitivity, specificity, associated predictive values and percentage of correct classification of caries in occlusal surface for caries in approximal surfaces

	Caries in occlusal surface	Prediction of caries in approximal surfaces (%)					
Tooth type	Prevalence (%)	Prevalence (%)	Sensitivity	Specificity	Correct classification (%)	PPV	NPV
6	71.1	11.5	83	51	54	18	95
E	78.8	63.4	80	58	72	76	62
D	61.5	75.9	73	57	67	73	57
All molars	88.4	87.5	78	70	75	78	70

Table V. Caries prevalence on free-smooth and approximal surfaces, sensitivity, specificity, associated predictive values and percentage of correct classification of caries in free-smooth surfaces for caries in approximal surfaces

	Caries in buccal-lingual surfaces	Prediction of caries in approximal surfaces (%)					
Tooth type	Prevalence (%)	Prevalence (%)	Sensitivity	Specificity	Correct classification (%)	PPV	NPV
6	43.2	11.5	46	57	55	13	88
E	50.9	63.4	60	65	62	75	49
D	15.4	75.9	22	90	50	77	44
All molars	63.4	87.5	59	65	61	75	48

Table VI. Odds ratio for presenting caries on approximal surfaces as predicted by caries presence in occlusal surface in different teeth and all molars in mixed dentition

	Caries in occlusal surfaces		Caries in approximal surfaces	
Tooth type	OR	95% CI	χ^2	*P* value
6	5.22	1.03–24.08	3.50	0.061
E	5.60	2.13–13.57	14.09	<0.000
D	3.70	1.61–8.63	8.69	0.003
Subject	8.62	3.53–21.04	22.79	<0.000

Table VII. Odds ratio for presenting caries on approximal surfaces as predicted by caries presence in free-smooth surfaces in different teeth and all molars in mixed dentition

	Caries in free-smooth surfaces		Caries in approximal surfaces	
Tooth type	OR	95% CI	χ^2	*P* value
6	1.14	0.35–3.67	0.00	0.940
E	2.95	1.28–6.80	5.70	0.016
D	2.77	0.84–9.10	2.14	0.143
Subject	2.77	1.00–6.00	5.01	0.025

non-significant predictive value for caries presence in the approximal surfaces was found (OR = 5.0; 95% CI = 1.03–24.08 ($P = 0.061$) and OR = 1.14; 95% CI = 0.35–3.67 ($P = 0.940$), respectively). In addition, free-smooth surface caries in Ds also presented a non-significant predictive value for approximal caries presence. Caries presence in all other teeth analyzed and in all posterior teeth had a significant predictive value for caries presence in the approximal surfaces. In those children who presented occlusal caries, above or equal to the threshold established in this study, OR was 8.62 (95% CI = 3.53–21.04 ($P < 0.000$)). Similarly, for those who had buccal-lingual caries, OR was 2.77 (95% CI = 1.00–6.00 ($P = 0.025$)).

Children presenting two or more carious occlusal surfaces in 2nd primary molars were at about 5.5 times greater risk of presenting caries in the approximal surfaces of these teeth, while those with the same teeth presenting one or more carious free-smooth surfaces were at about 3 times greater risk. When all molars were analyzed, the greatest OR for approximal caries presence was found when the occlusal surface was carious. Thus, children who presented 5 or more carious occlusal surfaces were at about 8.5 times greater risk of presenting caries in their approximal surfaces, while those with 2 or more carious free-smooth surfaces were at 2.8 times greater risk.

Discussion

In the prevention and treatment of dental caries, consideration needs to be given not only to individuals who are at greater risk, but also to the tooth surfaces that are more susceptible to caries [24]. With respect to clinically undetectable approximal caries, the diagnostic radiograph assumes a particular importance when one knows that lesion progression can be delayed, arrested, or even reversed before cavitation occurs. Although not perfect [25], the choice of radiographs in this study was to show loss of minerals more objectively than the clinical appearance does. Moreover, in clinical situations, there is a greater probability of diagnosing a lesion radiographically than finding it by visual inspection [26–28]. However, with regard to concerns

about ionic radiation exposure, it is important to identify those children who would probably benefit from certain dental radiographs and those who would not. Past caries experience has been recommended as an indication for performing supplementary radiographic diagnosis [16,17,29,30].

Clinically detectable caries in posterior tooth surfaces can therefore be used as a caries predictor for the approximal surface, and help in the making of decisions about bitewing radiographs. As previously described, associations between occlusal or free-smooth surfaces and approximal caries were detected in the present study [5,19,20]. Although the importance of detecting approximal caries with radiographic screening might be questioned when the caries prevalence is low, this was not the case in the present study, since the studied population presented a moderate caries prevalence.

Furthermore, in this population it is important to know whether a specific tooth surface is sound or carious, since appropriate caries prevention regimes may be applied, thereby saving costs and time.

When caries experience is used as a caries risk predictor, the commonly used and most pragmatic test characteristics are sensitivity, specificity, and associated predictive values. In this study, the sensitivity values ranged from to 22% to 83% and specificity from 51% to 90%. However, there was no indicator or combination of teeth with both high sensitivity and specificity indicating teeth or individuals at high risk of presenting posterior approximal caries. Furthermore, in no case did the predictive power reach the proposed combined sensitivity and specificity of 160%, which has been suggested as the minimum for a caries risk marker, in order to target individualized prevention [31]. The best combination for subjects ($Se = 78$; $Sp = 70$) equaled 148 when the occlusal surface was used as approximal caries predictor. Both free-smooth and occlusal surfaces may be considered to be predictors of approximal caries presence. However, better results were found when the status of occlusal surfaces was evaluated, since the highest percentage of correct classification (75%) was obtained. This may be partially explained, like the approximal surface, by the occlusal surface being more difficult to clean and presenting more difficult access to fluoride, and therefore more susceptible to caries development than the free-smooth surface [32,33]. Bjarnason & Gröndahl [5] examined the use of free-smooth surface in approximal caries prediction in permanent dentition, but the sensitivity values were lower while the specificity values were higher than those found in the current study. These differing results may be explained by the differences in approximal caries prevalence, different age range studied, and different methodologies used in the respective study.

Some children with occlusal or free-smooth caries are at increased risk of presenting approximal caries. Thus, subjects with a certain number of occlusal surface caries on primary molars were at 3.5 to 5.5 times greater risk of presenting caries in their approximal surfaces. However, only the children who presented at least one carious 2nd primary molar in free-smooth surfaces were at about 3 times greater risk of presenting carious approximal surfaces. The 1st permanent molar was the only tooth analyzed that presented a non-significant risk of presenting approximal caries when both occlusal and free-smooth surface caries was present. This may be related to the fact that at the evaluated age this tooth has been in the mouth for a relatively shorter period of time than the primary molars, and it was also expected that the studied children would have slower caries progression, since they lived in a fluoridated water supply region. Moreover, children were now enrolled in a dental assistance program, which could mean decreased caries prevalence in permanent dentition. In addition, all teeth that presented non-significant values for OR had a low caries prevalence in one of the two studied surfaces.

Since the occlusal surface showed the best results for predicting approximal caries, this is a more appropriate predictor for approximal caries presence and, consequently, for determining the necessity of taking bitewing radiographs. The probability of finding caries on the approximal surface is high when the child presents a certain number of carious occlusal surfaces, so the clinician must bear these findings in mind if accurate caries diagnoses are to be made.

The results of this study must be confirmed by longitudinal studies, however, since the predictive power values did not achieve the minimum value indicated by the literature. Nevertheless, it can be concluded that visually detectable caries lesions are indicative of approximal caries. Thus, if a certain risk limit is defined and the corresponding number of caries lesions in different surfaces is reached, indicating that the risk is above the threshold, this could be a practical guideline on the need for radiography in this age group of patients with "moderate caries experience".

Acknowledgments

We thank Professors Antonio Carlos Pereira and Marcelo de Castro Meneghim (State University of Campinas, Faculty of Dentistry of Piracicaba), who contributed to this investigation.

References

[1] Fennis-Ie YL, Verdonschot EH, van't Hof MA. Performance of some diagnostic systems in the prediction of occlusal caries in permanent molars in 6- and 11-year-old children. J Dent 1998;26:403–8.

[2] Kidd EA, Pitts NB. A reappraisal of the value of the bitewing radiograph in the diagnosis of posterior approximal caries. Br Dent J 1990;169:195–200.

[3] Espelid I, Tveit AB. A comparison of radiographic occlusal and approximal caries diagnosis made by 240 dentists. Acta Odontol Scand 2001;59:285–9.

[4] Skold UM, Klock B, Lindvall AM. Differences in caries recording with and without bitewing radiographs. A study on 5-year-old children in the County of Bohuslan, Sweden. Swed Dent J 1997;21:69–75.
[5] Bjarnason S, Gröndahl HG. Relationships between free smooth surface and proximal caries in the young permanent dentition. Community Dent Oral Epidemiol 1996;24:7–10.
[6] Hintze H. Screening with conventional and digital bite-wing radiography compared to clinical examination alone for caries detection in low-risk children. Caries Res 1993;27:499–504.
[7] Espelid I, Tveit A, Haugejorden O, Riordan PJ. Variation in radiographic interpretation and restorative treatment decisions on approximal caries among dentists in Norway. Community Dent Oral Epidemiol 1985;13:26–9.
[8] Gröndahl HG, Lith A, Jonsson G, Persson Y. Approximal caries and frequency of bitewing examinations in Swedish children and adolescents. Community Dent Oral Epidemiol 1992;20:20–4.
[9] Kantor ML. Trends in the prescription of radiographs for comprehensive care patients in U.S and Canadian dental schools. J Dent Educ 1993;57:794–7.
[10] Pienihäkkinen K, Jokela J, Alanen P. Assessment of caries risk in preschool children. Caries Res 2004;38:156–62.
[11] Wilson RF, Ashley FP. Identification of caries risk in schoolchildren: salivary buffering capacity and bacterial counts, sugar intake and caries experience as predictors of 2-year and 3-year caries increment. Br Dent J 1989;167: 99–102.
[12] Disney JA, Graves RC, Stamm JW, Bohannan HM, Abernathy JR, Zack DD. The University of North Carolina Caries Risk Assessment Study: further developments in caries risk prediction. Community Dent Oral Epidemiol 1992;20: 64–75.
[13] Alaluusua S. Salivary counts of mutans streptococci and lactobacilli and past caries experience in caries prediction. Caries Res 1993;27:68–71.
[14] Mattiasson-Robertson A, Twetman S. Prediction of caries incidence in schoolchildren living in a high and a low fluoride area. Community Dent Oral Epidemiol 1993;21:365–9.
[15] Raitio M, Pienihakkinen K, Scheinin A. Assessment of single risk indicators in relation to caries increment in adolescents. Acta Odontol Scand 1996;54:113–17.
[16] Stephens RG, Kogon SL, Reid JA. Non-invasive therapy for proximal enamel caries. An expanded role for bitewing radiography. J Can Dent Assoc 1987;53:619–22.
[17] Lith A, Gröndahl HG. Intervals between bitewing examinations in young patients when applying a radiologic algorithm. Community Dent Oral Epidemiol 1992;20:181–6.
[18] Mileman P, van der Weele L, van de Poel F, Purdell-Lewis D. Dutch dentists' decisions to take bitewing radiographs. Community Dent Oral Epidemiol 1988;16:368–73.
[19] Neilson A, Pitts NB. The clinical behavior of free smooth surface carious lesions monitored over 2 years in a group of Scottish children. Br Dent J 1991;171:313–18.
[20] Bimstein E, Eidelman E, Klein H, Chosack A. Distribution of caries in different tooth surfaces in 7-year-old children. Caries Res 1981;15:324–30.
[21] WHO. Oral health surveys: basic methods, 4th edn. Geneva: WHO; 1997.
[22] Fleiss JL, Slakter MJ, Fischman SL, Park MH, Chilton NW. Inter-examiner reliability in caries trials. J Dent Res 1979;58:604–9.
[23] Wong MCM, Schwartz E, Lo ECM. Patterns of dental caries severity in Chinese kindergarten children. Community Dent Oral Epidemiol 1997;25:343–7.
[24] Chestnutt IG, Schafer F, Jacobson AP, Stephen KW. Incremental susceptibility of individual tooth surfaces to dental caries in Scottish adolescents. Community Dent Oral Epidemiol 1996;24:11–16.
[25] Marthaler TM, Germann M. Radiographic and visual appearance of small smooth surface caries lesions studied on extracted teeth. Caries Res 1970;4:224–42.
[26] Mann J, Pettigrew JC, Revach A, Arwas JR, Kochavi D. Assessment of the DMF-S index with the use of bitewing radiographs. Oral Surg Oral Med Oral Pathol 1989;68:661–5.
[27] de Vries HC, Ruiken HM, Konig KG, van't Hof MA. Radiographic versus clinical diagnosis of approximal carious lesions. Caries Res 1990;24:364–70.
[28] Poorterman JH, Weerheijm KL, Groen HJ, Kalsbeek H. Clinical and radiographic judgement of occlusal caries in adolescents. Eur J Oral Sci 2000;108:93–8.
[29] Matteson SR, Morrison WS, Stanek EJ 3rd, Phillips C. A survey of radiographs obtained at the initial dental examination and patient selection criteria for bitewings at recall. J Am Dent Assoc 1983;107:586–90.
[30] Lith A, Grondahl HG. Predicting development of approximal dentin lesions by means of past caries experience. Community Dent Oral Epidemiol 1992;20:25–9.
[31] Kingman S. Researchers confirm AIDS epidemic in Africa. Br Med J 1993;306:1564.
[32] Berman DS, Slack GL. Caries progression and activity in approximal tooth surfaces. A longitudinal study. Br Dent J 1973;134:51–7.
[33] Pearce E, Larsen M, Coote G. Fluoride in enamel lining pits and fissures of the occlusal groove-fossa system in human molar teeth. Caries Res 1999;333:196–205.