Caries Risk Assessment in an Educational Environment

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Abstract: This study was designed to assess, retrospectively using dental records, the impact on the management of dental caries of new caries risk assessment (CRA) forms and procedures introduced into a predoctoral dental school clinic. Of 3,659 patients with a new patient visit (NPV) and baseline exam (BE) in the two-year period of July 2003 through June 2005, 69 percent (n= 2,516) had a baseline CRA. "Visible cavitation or caries into dentin by radiograph" was significantly correlated to most items included in the CRA form, for example, "frequent between meal snack of sugars/cooked starch" ($p<0.001$), "inadequate saliva flow" ($p=0.03$), and "deep pits and fissures or developmental defects" ($p<0.001$). Fluoride toothpaste use (odds ratio, OR=0.7) was negatively related to cavitation risk while "readily visible heavy plaque on teeth" (OR=2.0), "frequent between meal snack of sugars/cooked starch" (OR=1.6), "interproximal enamel lesions or radiolucencies" (OR=11.8), and "white spots or occlusal discoloration" (OR=1.50) were positively related. CRA use at follow-up, the use of bacterial tests, antibacterial therapy, and specific patient recommendations were all very low. While the content and usefulness of the CRA procedures were validated, the study highlighted the difficulties of implementing such programs in educational establishments even with an extensive student didactic program and faculty training.

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Traditionally, dental caries has been managed simply by detecting cavities or precavitated lesions followed by drilling and filling. In recent years, a better understanding of the caries process has changed this operative treatment philosophy: preventive strategies involving fluoride and remineralization are preferred, and operative treatments are undesirable unless the carious lesion has reached cavitation.[1-3] The clinical decision making process should be based first on a caries risk assessment (CRA).[4-7] Two different approaches to CRA can be described as the risk model and the prediction model.[8] The risk model identifies causative caries factors also called risk factors but does not predict the caries outcome. The prediction model is the assessment of the risk of caries progression in the future: it represents the next step beyond the risk model. Several multivariable caries risk strategies have been developed. Zero et al.[9] systematically reviewed the then available multivariable caries risk assessment strategies. Since the publication of their review in 2001, only five studies related to CRA have been published.[6,7,10-12] Zero et al.'s conclusion that there is a need for further research to identify and validate CRA strategies, especially for adults,[9] is still valid. Only one[10] of the five recent studies concerned adults rather than children or elderly people.

In April 2002, a consensus conference was held in Sacramento, California, on the topic of "Caries Management by Risk Assessment" (CAMBRA). An expert panel designed a CRA form and proposed its use based upon the known literature at that time. All supporting review articles and the reports and summaries from this CAMBRA consensus, along with the CRA forms and intervention procedures, were published in the *Journal of the California Dental Association* in February/March 2003 and are accessible at www.cdafoundation.org/journal.[13] The CRA forms and procedures were introduced into the predoctoral dental teaching clinic at the University of California, San Francisco (UCSF) in January 2003 on a pilot basis and fully in July 2003. The caries risk factors included in the form were a combination of pathological factors and protective factors that were assumed to be able to be used in combination to assess overall caries risk and to guide therapy and

treatment planning. These factors can be accessed in detail at the above website and, in brief, correspond with the listing in the results given in Table 4 below. The form was designed to fit on one page for ease of use clinically. A second one-page form summarizing patient recommendations was also introduced, so that patients could take a written record home with them. Beginning in July 2003, the CRA forms were introduced for use at the baseline exam for all patients.

The main purpose of our study was to assess, retrospectively using dental charts, the impact of the new CRA forms and procedures introduced into the UCSF predoctoral dental teaching clinics in July 1, 2003, with a follow-up data collection that extended until June 30, 2005. More particularly, relationships between risk indicators (items such as race/ethnicity that may indicate caries risk but are not factors that directly influence the caries process), risk factors (items such as frequency of ingestion of carbohydrates that may have a direct influence on the caries process), and overall caries risk were assessed. Also as "visible cavitation or caries into dentin by radiograph" is the most obvious sign of high caries risk level, relationships of this criterion with the risk indicators and risk factors were also investigated.

Materials and Methods

This study was conducted retrospectively using electronic data and paper charts from UCSF predoctoral dental school patients. To preserve the anonymity of the respondents, a specific identification number different from the one used in the charts was used. The research project had received the approval of the Committee on Human Research (the institutional review board) of UCSF.

A list of the patients aged over six years who had a new patient visit (NPV) between July 1, 2003, and June 30, 2005, was generated with the electronic Axium informatics system of the UCSF dental school. The generated file also contained demographic variables: age, gender, race/ethnicity, type of dental insurance, and year of dental student practitioner. At the NPV, there is generally insufficient time to conduct a full baseline exam, so this is scheduled for a later visit. In the report, date of baseline examination (BE) and a caries risk assessment (CRA) were abstracted if available. The caries risk assessment was designed to be carried out as part of the baseline examination, following the clinical exam. Patients who have an NPV do not necessarily go on to have a BE, although those who have a BE should also have a CRA. Thus, 6,848 patients aged over six years with an NPV for the two-year period from July 1, 2003, to June 30, 2005, were included. Among the overall sample, 3,659 patients had an NPV and a BE, and 2,516 patients had a baseline CRA.

Eighty-two patients with complete dentures examined during the study period were excluded. Eighty-three charts could not be located. Therefore, paper charts of 2,351 patients were consulted, and all items relating to the baseline CRA (conducted as described on the web at www.cdafoundation.org/journal[13]) and for potential CRA follow-up were entered into Microsoft Excel. The chart reviews were done by one person (SD-O). The results are presented below for two academic years: period 1 from July 1, 2003, to June 30, 2004, and period 2 from July 1, 2004, to June 30, 2005. The two years were analyzed both separately and together. Where appropriate, the results are presented separately, so that an assessment of progress with the implementation of the caries management program from year to year can be made.

In this descriptive study, all the variables were categorial. The analysis was done by using simple statistical analysis (descriptive and bidimensional) with the statistical software SPSS 13.0. The χ^2 test was used to test the relationship between variables with a 5 percent level of significance. Since 42 percent of the CRA forms for the subjects were missing overall caries risk status for period 1, we were unable to assess the relationship of individual factors with overall caries risk.

To allow comparisons between the characteristics of the study population and the 2000 census data for San Francisco, age groups were defined as in the census. For statistical analysis, the five age groups were: 1) under thirty-one years; 2) thirty-one to forty years; 3) forty-one to fifty years; 4) fifty-one to sixty years; and 5) over sixty years. Subjects were identified as having one of three different payment account types from the electronic patient records: 1) cash; 2) Denti-Cal (California Medi-Cal insurance for low income patients); and 3) others (neither cash nor Denti-Cal). Subjects' ethnicity was designated as white, black, Asian, Hispanic, and other.

A logistic regression analysis with forward stepwise selection, alpha entry, and stay criteria of 0.05 was conducted to investigate the potential relationship of risk factors to the presence of "visible cavitation or caries into dentin by radiograph" while adjusting for other factors.

Results

Demographic Data

Demographics are displayed together with the 2000 census data for San Francisco (SF) for comparison in Table 1. Patients attending the UCSF predoctoral dental clinics between July 2003 and June 2005 included fewer children (generally children under eighteen years attend the separate pediatric dentistry clinic), and thus the patient population was comprised of more thirty-five to sixty-four year olds than the SF census data. The UCSF clinic included fewer Asians and more blacks, Hispanics, and those of unspecified race/ethnicity. But the group of patients with an NPV, BE, and baseline CRA between July 1, 2003, and June 30, 2005, matches the patients who had an NPV in terms of age, gender, and ethnicity. Also, the populations of periods 1 and 2 were very similar to the overall population of the patients who had an NPV, BE, and baseline CRA.

Of the 3,659 patients with an NPV and BE, 68.8 percent had a baseline CRA (n=2,516). For account type, cash accounts were more likely to have a baseline CRA than Denti-Cal and others (p=0.004) (Table 2). There was no statistically significant difference between patients who had a baseline CRA and those who did not with regard to gender, age, or ethnicity.

Baseline CRA and "Overall Caries Risk"

One of the items in the CRA form was "overall caries risk." This was assessed as low, moderate, or high based on the balance between pathological and protective caries risk factors on the CRA form. Students and their supervising faculty were trained to make this overall caries risk assessment by taking into consideration the yes and no answers to the questions on the CRA form and making a judgment as to whether the caries balance swings towards the appearance of carious lesions in the future or the protective factors are likely to prevail. Among the 2,351 paper charts, 1,133 patients had their baseline CRA from July 1, 2003, to June 30, 2004 (period 1) and 1,218 from July 1, 2004, to June 30, 2005 (period 2). The item "overall caries risk" was not completed in 478 (42 percent) forms from period 1 or 244 (20 percent) of period 2. Because the percentage of missing entries for this item was so high in period 1, the analysis of the overall caries risk was undertaken only for period 2.

In period 2, among the 974 patients who had an overall caries risk, 21.8 percent were classified as low risk, 31.3 percent as moderate risk, and 46.9 percent as high risk.

Risk Indicators. In period 2, the caries risk level as assessed at baseline was related to gender, account type, and ethnicity. Males were at higher risk than females (p=0.002). African Americans and Hispanics had significantly higher risk than other races (p=0.014). Denti-Cal patients were at higher risk than patients who had another account type (p<0.001). Age of the patients was not significantly related to the assessed caries risk level (p>0.05).

Risk Factors. In period 2, the assessed caries risk level was related to most of the items included in the CRA form: "visible cavitation or caries into dentin by radiograph" (p<0.001), "caries restored in the last

Table 1. Percentage of gender, age, and ethnicity of San Francisco (2000 census) and patients involved in the present study

	Gender		Age					Race/Ethnicity*				
	Male	Female	1-19	20-34	35-54	55-64	+65	White	Black	Asian	Hispanic	Other
SF 2000 Census	51	49	16	30	31	8	14	53	9	33	14	10
NPV	48	52	1	26	38	16	18	48	14	14	19	5
NPV+BE+BaseCRA	49	51	1	26	38	17	17	50	12	16	18	5
Period 1	49	51	1	29	38	16	16	51	12	16	18	3
Period 2	49	51	2	26	39	17	16	49	12	16	18	6

NPV: N=6,848 with an NPV between July 1, 2003, and June 30, 2005.
NPV+BE+BaseCRA: N=2,516 with a NPV+BE+BaseCRA between July 1, 2003, and June 30, 2005,
Period 1: N=1,133 with CRA between July 1, 2003, and June 30, 2004, and for whom the charts were consulted,
Period 2: N=1,218 with CRA between July 1, 2004, and June 30, 2005, and for whom the charts were consulted.
*US 2000 census allowed >1 race; race and ethnicity (Hispanic: yes/no) were asked separately.

three years" (p<0.001), "readily visible heavy plaque on teeth" (p<0.001), "frequent between meal snack of sugars/cooked starch" (p<0.001), "inadequate saliva flow" (p=0.002), "exposed roots" (p<0.001), "deep pits and fissures or developmental defects" (p<0.001), "interproximal enamel lesions or radiolucencies" (p<0.001), "white spots or occlusal discoloration" (p<0.001), "recreational drug use" (p=0.006), "daily use of fluoride toothpaste" (p=0.008), and "daily use of fluoride mouthwash" (p=0.001). Patients who had visible cavitation or caries into dentin by radiograph were classified at higher risk than those who had none (p<0.001). Patients who had caries restored in the last three years were at higher risk (p<0.001). The assessed caries risk level was not related to the presence of fixed or removable appliances, water fluoridation, xylitol gum use, or chlorhexidine rinse use (all p>0.05).

In period 2, only forty-six patients had a mutans streptococci and a lactobacilli count recorded in the paper charts. Saliva flow was assessed physically for fifty-one patients and was based on a visual examination for 1,038 patients. The physical assessment of saliva flow was made by having the patient chew for three minutes on the paraffin stick provided in the CRT kit and expectorate into a measuring cup. Stimulated saliva flow was considered inadequate if it was less than 0.7 ml/min. According to the entries in the charts, 674 of 1,218 patients (55 percent) were given recommendations after the baseline CRA (thirty-five did not, and 509 were missing). Due to the high percentage of missing data (41.8 percent), no statistical analysis of the different recommendations proposed to the patients concerning the management of caries risk was performed.

Baseline CRA and "Visible Cavitation or Caries into Dentin by Radiograph"

As "visible cavitation or caries into dentin by radiograph" is an obvious sign of high caries risk, relationships between this criterion and risk indicators and risk factors were investigated among the baseline CRA completed between July 1, 2003, and June 30, 2005.

Table 2. Cross tabulation presenting the differences in account type and having a baseline CRA among the patients who had an NPV and a BE between July 1, 2003, and June 30, 2005

N=3659	Baseline CRA	Total	Significance (p-value)
Cash	1550 (71%)	2189	
Denti-Cal	564 (66%)	852	0.004
Others	402 (65%)	618	

Risk Indicators. Gender (p<0.001), account type (p=0.001), age (p=0.002), and ethnicity (p=0.01) were significantly correlated with the presence of "visible cavitation or caries into dentin by radiograph." (See Table 3.)

Risk Factors. Among the baseline CRA completed between July 1, 2003, and June 30, 2005, the presence of "visible cavitation or caries into dentin by radiograph" was significantly correlated to most items included in the CRA form as summarized in Table 4. For example, "frequent between meal snack of sugars/cooked starch" (p<0.001), "inadequate saliva flow" (p=0.027), and "deep pits and fissures or developmental defects" (p<0.001) were significant. There was no significant relationship between "fixed or removable appliances," "exposed roots," "water fluoridation," "xylitol gum use," or "chlorhexidine

Table 3. Cross tabulation between potential risk indicators and the presence of "visible cavitation or caries into dentin by radiograph"

N=2351		Visible Cavitation or Dentinal Caries	Total	Significance (p-value)
Gender	Male	691 (64%)	1073	<0.001
	Female	632 (57%)	1118	
Account type	Cash	827 (59%)	1398	0.001
	Denti-Cal	325 (67%)	482	
	Other	191 (56%)	340	
Age group	≤30	311 (67%)	465	0.002
	31-40	279 (61%)	459	
	41-50	246 (60%)	413	
	51-60	249 (62%)	403	
	≥61	258 (54%)	480	
Ethnicity	White	651 (59%)	1099	0.010
	Asian	193 (56%)	345	
	Black	170 (66%)	257	
	Hispanic	272 (65%)	416	
	Other	52 (54%)	97	

rinse use" with "visible cavitation or caries into dentin by radiograph." Table 4 also presents the odds ratios (ORs) with 95 percent confidence intervals (CIs). These values indicate the strength of the relationships as well as the direction. For example, fluoride toothpaste and fluoride mouthrinse use have values less than 1.0, indicating a negative relationship with cavitation risk.

Table 5 presents the results of the stepwise logistic regression analysis that was conducted to investigate the potential relationship of risk factors to the presence of "visible cavitation or caries into dentin by radiograph" while adjusting for other factors. The model indicated that the factors "readily visible heavy plaque on teeth" (OR=2.03), "frequent between meal snack of sugars/cooked starch" (OR=1.57), "interproximal enamel lesions or radiolucencies" (OR=11.83), and "white spots or occlusal discoloration" (OR=1.50) were positively related to the "visible cavitation or caries into dentin by radiograph" in a stepwise regression.

Follow-Up CRA

Among the 2,351 patients who had an NPV, BE, and baseline CRA between July 1, 2003, and June 30, 2005, only eighty-nine patients had a follow-up CRA. The follow-up CRA was done a mean of fourteen months after the baseline CRA (SD=4.5). Twenty-seven percent of patients (n=24) who had a follow-up CRA did not have the overall caries risk

Table 4. Cross tabulation between potential risk factors and the presence of "visible cavitation or caries into dentin by radiograph"

N=2351		Visible Cavitation or Dentinal Caries	Total	Significance (p-value)	Odds Ratio	95% CI
Pathological Indicators/Factors						
Restorations in last three years	No	772 (56%)	1370	<0.001	1.59	1.33, 1.91
	Yes	537 (67%)	798			
Visible plaque	No	419 (46%)	906	<0.001	2.75	2.30, 3.28
	Yes	869 (70%)	1237			
Frequent snack	No	761 (55%)	1387	<0.001	1.91	1.58, 2.31
	Yes	519 (70%)	742			
Inadequate saliva flow	No	1065 (59%)	1796	0.027	1.37	1.03, 1.80
	Yes	169 (67%)	254			
Fixed or removable appliances	No	957 (60%)	1591	0.927	0.99	0.80, 1.22
	Yes	284 (60%)	474			
Exposed roots	No	619 (59%)	1050	0.285	1.10	0.93, 1.30
	Yes	680 (61%)	1111			
Deep pits and fissures	No	860 (56%)	1540	<0.001	1.93	1.58, 2.37
	Yes	423 (71%)	596			
Interproximal enamel lesions	No	468 (39%)	1202	<0.001	13.55	10.57, 17.37
	Yes	769 (90%)	858			
White spots	No	684 (51%)	1351	<0.001	3.26	2.66, 3.98
	Yes	581 (77%)	755			
Recreational drugs	No	1092 (59%)	1860	<0.001	2.03	1.50, 2.75
	Yes	179 (74%)	241			
Protective Factors						
Fluoridated community	No	107 (64%)	166	0.213	0.81	0.58, 1.13
	Yes	1160 (60%)	1949			
Fluoride toothpaste	No	111 (69%)	161	0.020	0.67	0.47, 0.94
	Yes	1179 (60%)	1977			
Fluoride mouthwash	No	1055 (62%)	1703	0.006	0.74	0.59, 0.92
	Yes	228 (55%)	418			
Xylitol gum	No	1206 (61%)	1989	0.805	0.95	0.66, 1.39
	Yes	72 (60%)	121			
Chlorhexidine	No	1255 (61%)	2076	0.797	0.92	0.47, 1.79
	Yes	21 (58%)	36			

determined at baseline; consequently, there was insufficient information to examine follow-up relationships for this item. Of these eighty-nine follow-up patients, nine had a bacteria count for mutans streptococci and lactobacilli recorded at baseline. Sixteen patients had some recommendations given at the baseline CRA; forty-one had none at baseline but some at the follow-up CRA; seven had no recommendations given at baseline nor at follow-up CRA; and information regarding recommendations was missing for twenty-five charts.

Table 5. Stepwise logistic regression related to the presence of "visible cavitation or caries into dentin by radiograph"

N=2351	Significance (p-value)	Odds Ratio	95% CI
Visible plaque	<0.001	2.03	1.58, 2.62
Frequent snack	0.001	1.57	1.19, 2.05
Interproximal enamel lesions	<0.001	11.83	8.62, 16.23
White spots	0.007	1.50	1.12, 2.01

Significant associations for the follow-up group are presented in Table 6. "Visible cavitation or caries into dentin by radiograph" at baseline ($p<0.001$), the assessed level of overall caries risk at baseline ($p=0.019$), and the presence of interproximal enamel lesions or radiolucencies at baseline ($p=0.005$) were each significantly related to "visible cavitation or caries into dentin by radiograph" at follow-up (Table 6).

The associations with the other items were not significant, or they were impossible to assess because of the low numbers of patients in each subgroup.

Discussion

This study was designed to assess, retrospectively using charts, the impact on the management of dental caries of the new CRA forms and procedures introduced into the UCSF predoctoral dental clinic in 2003. The population of this study does not exactly represent the population of San Francisco (2000 U.S. census data). However, the group of patients used for statistical analysis matched the overall population of patients attending the predoctoral UCSF dental clinic, therefore representing the patient population attending the UCSF dental clinic.

Limitations of the study include the retrospective nature of the design and the relatively high percentage of missing data. As with all retrospective studies, only the information on the forms used in the clinics or recorded in the electronic database was available for assessment; we could not introduce new forms or revised CRA forms, for example. Moreover, as with many chart reviews, practitioners sometimes only record information in the charts if it existed, but might not have always formally recorded that something did not exist in the chart. Thus, items missing in more than 20 percent of patients were excluded from analysis.

Although risk assessment approaches should be validated in everyday practice settings,[14] most of the

Table 6. Cross tabulation between "visible cavitation or caries into dentin by radiograph" at baseline, "overall caries risk" at baseline, "interproximal enamel lesions or radiolucencies," and the presence of "visible cavitation or caries into dentin by radiograph" at follow-up

N=89		Visible cavitation or dentinal caries AT FOLLOW-UP	Total	Significance (p-value)	Odds Ratio	95% CI
Visible cavitation or dentinal caries AT BASELINE	No	8 (22%)	37	<0.001	7.25	2.64, 19.95
	Yes	28 (67%)	42			
Assessed caries risk AT BASELINE	Low	5 (31%)	16	0.019	2.31	1.13, 4.73
	Moderate	10 (42%)	24			
	High	14 (70%)	20			
Interproximal lesions AT BASELINE	No	16 (33%)	48	0.005	4.57	1.57, 13.35
	Yes	16 (70%)	23			

studies in this field have been conducted under clinical trial conditions in children or elderly people.[9,15] A recent study by Bader et al.[10] validated an approach to CRA among a large sample of patients consulting in private practice. The mean age of subjects in the Bader et al. study ranged between forty-eight and fifty-three years within the subgroups, but the authors did not give further information concerning the age distribution of the study's overall population. Our study was conducted under routine (everyday) practice conditions in a predoctoral teaching clinic and in a population primarily consisting of adults aged between twenty and fifty-four years. It is expected therefore that the results will apply to adults in general. Moreover, this study is the first undertaken among adults in an educational environment. Stamm et al.[16] suggested that "it is recognized that any model, regardless of its ultimate accuracy, would have to be based on a data collection system that is relatively quick, inexpensive, and requires a limited armamentarium and be acceptable to those to whom it is applied." The CRA form and recommendation form used at UCSF are brief and concise and can also be used as a data collection method. In the first year of use of the CRA forms (period 1), only approximately 60 percent of the forms had overall caries risk assessed, even though the individual risk factors had been identified. This means that the students in the first year of CRA form use were filling out the form, but in 40 percent of cases were not assessing the caries risk status or at least not documenting it. In the second year, however, students completed this overall assessment of risk for over 80 percent of patients. Even if the first-year completion of the risk assessment was disappointing for the faculty and staff involved in the CRA, the results showed that completing the CRA form increased dramatically within these two academic years. Also, 70 percent of the patients who had a "visible cavitation or caries into dentin by radiograph" were classified as high risk. Even if this rate should theoretically be 100 percent,[13] this suggests that the presence of cavities has a significant weight in the students' decisions. Completing the CRA forms and the overall caries risk level determination must be done under faculty supervision. The findings from this study suggest perhaps that some teachers were not convinced or were still reluctant about the need for CRA for a reasoned and appropriate caries management program, even though we conducted faculty training before introducing the program. Many studies have already shown the wide variability among university teachers and their personal interpretation concerning treatment decisions in cariology.[17-19] Our findings reinforce the need to calibrate the dental faculty based on standardized criteria for treatment decisions in cariology.

The CAMBRA procedures introduced into the predoctoral teaching clinic in July 2003 included an instruction that, when a patient is assessed as high caries risk, then a bacterial assessment for mutans streptococci (MS) and lactobacilli (LB) is indicated. This instruction was not followed in most cases. Indeed, only forty-six patients had MS and an LB count recorded in the paper charts between July 1, 2004, and June 30, 2005 (period 2). A possible explanation of this very low number of bacteria tests could be the extra cost (approximately $10 U.S.) that is not covered by any insurance carrier. Patients needed to agree to pay the extra cost. This is prejudicial insofar as the bacterial counts are an important criterion to customize an appropriate caries management plan to the patient's needs; patients with high bacteria counts should be dispensed antibacterial treatment. Patients were also required to pay for the chlorhexidine antimicrobial treatment. The results of this review clearly show that, even in an environment where students and faculty are taught the importance of antimicrobial therapy as part of caries management, few have embraced the concept as yet and that payment for bacterial assessment and antimicrobial therapy is one of the barriers to success. Professionally provided preventive care is mostly not eligible for reimbursement, thus discouraging prevention and encouraging inappropriate interventions.

"Visible cavitation or caries into dentin by radiograph" is an obvious sign of high caries risk. The results showed significant relationships between the criterion "visible cavitation or caries into dentin by radiograph" and most of the other items included in the CRA form. The following items on the CRA form were all significantly related to visible cavitation: "caries restored in the last three years," "readily visible heavy plaque on teeth," "frequent between meal snack of sugars/cooked starch," "inadequate saliva flow," "deep pits and fissures or developmental defects," "interproximal enamel lesions or radiolucencies," "white spots or occlusal discoloration," "recreational drugs," "daily use of fluoride toothpaste," and "daily use of fluoride mouthwash." However, "fluoride toothpaste" or "mouthwash use" was negatively related. It is not surprising that each of these individual factors was significantly related since numerous previous studies have implicated them in the ongoing caries process. However, in our study

all these factors have been validated as contributors to caries risk assessment over time in an adult clinical practice environment. These results validate the choice of the criteria included in the CRA form as risk factors because they are strongly positively related to the presence of cavities in the mouth, with fluoride therapy being negatively related. Some limitations should be highlighted concerning the assessment of the saliva flow, which relied mainly on a visual and subjective inspection (only eighty physical measurements were made in periods 1 and 2). It was surprising not to find a relationship with the presence of "fixed or removable appliances." The absence of relationship with "exposed roots" could easily be explained by the age distribution of the patients (50 percent of them were aged between twenty and fifty-four years). Further, it was not possible to determine specifically whether the root caries, rather than frank cavities, was related to exposed roots.

In a recent review on caries risk assessment, Zero et al.[9] emphasized that most studies did not report the presence of noncavitated lesions, which have been shown to have predictive value.[20,21] In our study, in spite of the low number of follow-up CRA, it appeared that the presence of interproximal enamel lesions or radiolucencies at baseline was significantly related to "visible cavitation or caries into dentin by radiograph" at follow-up (OR=4.57). Because very few patient recommendations (including fluoride and antibacterial interventions) were given at CRA baseline, these results indicate that restorative treatment alone without management of risk factors does not solve the problem of ongoing caries and resulted in about 70 percent of these patients returning with new carious lesions in one to two years. But interestingly, forty-one patients who had no recommendations given at baseline were given written recommendations at the follow-up CRA, indicating a willingness and acceptance by the provider, at that time, that simply drilling and filling would not solve the caries problem.

Unfortunately, this study cannot validate the CRA form as a risk model since the rate of the given recommendations (only sixteen of those eighty-nine patients had some recommendation forms provided at the baseline CRA) did not allow the assessment of the outcome of the given recommendations on the caries risk level and the bacteria count at follow-up. That is, it was not possible to evaluate the clinical efficacy of specific preventive regimens. But, as the level of overall caries risk at baseline was significantly related to "visible cavitation or caries into dentin by radiograph" at follow-up, the CRA form can be considered a "prediction model" because patients classified as high risk were more likely to have cavities at follow-up.

The results of this study emphasize the difficulties of introducing practical caries risk assessment and management of caries as a disease into a teaching or general practice environment where the traditional approach has been that restorative dentistry fixes caries. At UCSF, we provide students with extensive didactic teaching and practical training, and we have made considerable efforts to bring faculty on board and to train them. Marked improvements are being seen each year, but change is an ongoing long-term process. Faculty and the administration have embraced all the concepts, but still the implementation and follow-up have been difficult to achieve. Within UCSF, a committee of dedicated faculty have planned, introduced, and followed through on the CAMBRA procedures. The success that we have had is largely due to their efforts to work with their peers. They continue to modify and improve the forms and procedures.

At UCSF, the CRA form and recommendation form became electronic as of July 2005. The forms can be entered and saved electronically, and recommendations printed for patients to take home. Also, prompts have now been included to help faculty and students utilize these tools. Improvements have been made such as the presence of a frank cavity indicating that the patient is at high risk and requires a bacteria test. It is anticipated that better use will now be made of these tools and that outcomes assessment of therapy can be made in the future. A follow-up study will be needed to assess the success of these changes. The results of the present study also reinforce the need for ongoing training and retraining of faculty in these new procedures and their use as part of treatment planning.

UCSF is leading an initiative for all dental schools on the west coast of the United States to incorporate CRA procedures into their teaching clinics. Meetings are held annually at which experiences, new ideas, and procedures are shared for all to embrace. Dental schools in Indianapolis, New York City, Iowa, Jerusalem, and Adelaide, Australia, are also involved in the present cooperative educational initiative. Each school is attempting to introduce caries management by risk assessment. The lessons learned at UCSF, as reported here, should help other schools to effectively introduce CAMBRA.

In summary, the CRA forms used at UCSF over the last two years have been validated for a prediction

model, and the improved implementation of caries management by risk assessment (CAMBRA) is in process. The lessons learned, as spelled out in this report, will hopefully help others to achieve success more quickly. It has been postulated that the predictive validity of a CRA model depends strongly on the caries prevalence and characteristics of the population for which they are designed.[9] It is now time for the UCSF caries risk assessment forms and procedures to be used and tested among other populations.

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