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Restorative treatment thresholds for interproximal primary caries based on radiographic images

Findings from the Dental Practice-Based Research Network

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This study sought to quantify the depths of proximal caries lesions that lead dentists in regular clinical practice to intervene restoratively, based on hypothetical scenarios that present radiographic images and patient background information, and to identify characteristics associated with restorative intervention in lesions that have penetrated only the enamel surface. This study surveyed dentists from the Dental Practice-Based Research Network (DPBRN) who had reported doing at least some restorative dentistry ($n = 901$). Dentists were asked to indicate the depth at which they would restore a lesion, based on a series of radiographic images depicting interproximal caries at increasing lesion depths in a mandibular premolar; in addition, the dentists were questioned regarding two caries risk scenarios: one involving a patient with low caries risk and another involving a patient at higher risk. Logistic regression was used to analyze associations between the decision to intervene restoratively and specific dentist, practice, and patient characteristics.

Of the 901 DPBRN practitioner-investigators, 500 (56%) completed the survey. For a high caries risk patient, 66% of respondents indicated that they would restore a proximal enamel lesion, while 24% would do so once the lesion had reached into the outer third of the dentin. For a low caries risk patient, 39% of respondents reported that they would restore an enamel lesion, and 54% would do so once the lesion had reached into the outer third of the dentin. In multivariate analyses that accounted for dentist and practice characteristics, dentists in large group practices were less likely to intervene surgically for enamel caries, regardless of patient's caries risk.

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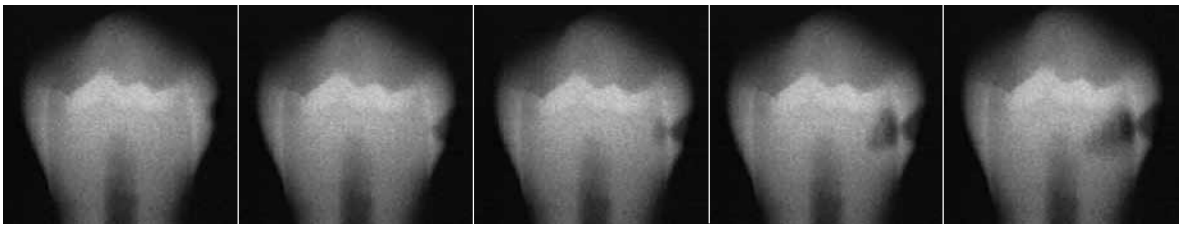
The interproximal tooth surface is considered an important and challenging site for the diagnosis and treatment of dental caries.[1,2] Criteria for treating interproximal caries with restorative intervention have been discussed extensively in the literature and substantial variations exist among clinicians as to when this treatment should be performed.[3-12]

Visual examination of interproximal surfaces is difficult and radiography can assist in diagnosing caries on these surfaces.[13-17] Radiographs reveal 88% more lesions on interproximal surfaces compared to visual examinations alone and have shown acceptable levels of correlation with microbiological evaluation.[13,14,18] However, radiograph interpretation involves a certain degree of subjectivity, particularly when lesions approach the dentin surface.[18] As a result, dentists may over- or underestimate the depth of interproximal lesion penetration.[19,20] Interproximal lesions involving the dentin surface are a controversial issue in terms of both clinical diagnosis and treatment approaches.[18,21,22]

Appropriate treatment thresholds become a critical issue for clinicians who might prematurely opt for restorative treatment by relying only on the depth of caries penetration without considering that cavitation might be present. Studies have attested to changes in the disease pattern of dental caries.[23,24] In the absence of cavitation, caries that have penetrated the enamel or dentin surfaces do not require surgical treatment but can be arrested through the remineralization process.[25-27]

While not all interproximal caries restorative treatment thresholds have been validated, confining the restorative intervention of non-cavitated caries to enamel is inappropriate. A consensus has been reached concerning the potential for non-cavitated enamel lesions to reverse.[28] Extensive research shows that enamel lesions that are not

Case scenario:
The patient is a 30-year-old female with no relevant medical history. She has no complaints and is in your office today for a routine visit. She has been attending your practice on a regular basis for the past six years.



Case 1 Case 2 Case 3 Case 4 Case 5

Please indicate the one [case] number that corresponds to the lesion depth at which you would do a permanent restoration (composite, amalgam, etc.) instead of doing only preventive therapy

1. If the patient has no dental restorations or dental caries and is not missing any teeth.

2. If the patient has 12 teeth with existing dental restorations, heavy plaque and calculus, multiple Class V white spot lesions, and is not missing any teeth.

Images from: Espelid I, Tveit AB, Fjelltveit A. Caries—New knowledge or old truths? Nor Dent J 1997;101:60-69. Reprinted with permission.

Fig. 1. Scenarios asked of participating dentists.[42]

cavitated can be arrested through a combination of proper fluoride treatment and patient education.[29-37]

It is important to understand the extent to which clinicians employ enamel-based thresholds when deciding whether to intervene restoratively. Understanding this threshold may allow dentists to provide more appropriate treatment plans in regular clinical practice. This study addressed features of that process by quantifying the distribution of radiographic thresholds for restorative intervention among a diverse group of dentists in regular clinical practice. In addition, dentists' personal and practice characteristics that are associated with enamel-based thresholds were assessed.

The study was conducted by the Dental Practice-Based Research Network (DPBRN), a consortium of dental practices with a broad representation of practice types, treatment philosophies, and patient populations. Among its practitioners and their patient populations, the DPBRN has substantial diversity in terms of race, ethnicity, socioeconomic status, geography, and rural/urban area of residence.[38,39]

This study sought to quantify the depth of a proximal caries lesion at which a dentist would intervene restoratively, based on hypothetical scenarios involving radiographic images and patient background information, and to identify characteristics associated with restorative intervention in proximal lesions that have penetrated the enamel only.

Materials and methods

The cross-sectional study design employed a questionnaire, administered once to all DPBRN dentist practitioner-investigators whose DPBRN enrollment questionnaire indicated that they perform at least some restorative dentistry in their practices (n = 901). The study was approved by the respective Institutional Review Boards (IRB) of all participating regions. As part of enrollment in the DPBRN, all practitioner-investigators complete an enrollment questionnaire about their practice characteristics and themselves. This questionnaire is available publicly at http://www.dentalpbrn.org/uploadeddocs/DPBRN%20Enrollment%20Questionnaire.pdf.

This report provides results based on questions from the DPBRN "Assessment of Caries Diagnosis and Treatment" questionnaire. The full questionnaire is the DPBRN's first study to involve all five DPBRN regions and is available publicly online.[40] Methodologic particulars, such as sample selection, recruitment process, length of the field phase, data collection process, procedures used during a pilot study, and pre-testing of the questionnaire, were reported in another study.[41]

Participants selected their recommended treatment from case options

Table 1. Dental practice characteristics tested for their association with the treatment options chosen by DPBRN practitioner-investigators.

Dentist's individual characteristics
Years since graduation from dental school
Race/ethnicity
Gender
Practice setting
Practice busyness*
Waiting time for restorative dentistry
DPBRN region of practice
Type of practice†
Patient population
Dental insurance coverage
Percentage of patients who self-pay
Age distribution
Racial/ethnic distribution
Dental procedure characteristics
Percentage of patient contact time spent each day doing restorative procedures‡
Percentage of patient contact time spent each day doing esthetic procedures‡
Percentage of patient contact time spent each day doing extractions§
Whether caries risk is assessed as a routine part of treatment planning

* Subcategories in the enrollment questionnaire: 1 = too busy to treat all people requesting appointments; 2 = provided care to all who requested appointments, but the practice was overburdened; 3 = provided care to all who requested appointments, and the practice was not overburdened; 4 = not busy enough—the practice could have treated more patients.

† Subcategories in the enrollment questionnaire: 1 = solo or small group private practice; 2 = large group practice; 3 = public health practice.

‡ Subcategories in the enrollment questionnaire: 0 = none; 1 = 1–30% of the time; 2 = 31–50% of the time; 3 = more than 50% of the time.

§ Subcategories in the enrollment questionnaire: 0 = none; 1 = 1–20% of the time; 2 = 21–30% of the time; 3 = more than 30% of the time.

presented in the questionnaire and were presented with a case scenario describing the patient's characteristics and a series of five radiographic images taken during the progressive stages of caries (located on the interproximal surface of a mandibular premolar) that portrayed increasingly deep carious lesions.[42] The shallowest depth at which the dentist would restore the tooth was requested for two different caries risk conditions: a situation where the patient had minimal risk, and a situation where the patient was at higher risk for caries. Figure 1 presents the images and exact wording for each case scenario. Case 1 presented a radiolucency in the outer half of the enamel; Case 2 had a radiolucency reaching the inner half of the enamel; and Cases 3, 4, and 5 showed radiolucencies in the outer, middle, and inner thirds of dentin, respectively.[42]

Dentists also were asked about assessment of caries risk ("Do you assess caries risk for individual patients in any way?"). Information regarding dentists' demographics and practice characteristics (see Table 1) had been gathered from the enrollment questionnaire.

Study population

This study queried dentists participating in the DPBRN, which consists of outpatient dental practices affiliated to investigate research questions and share experiences and expertise. The DPBRN comprises five regions: Alabama/Mississippi (AL/MS); Florida/Georgia (FL/GA); dentists employed by HealthPartners and private practitioners in Minnesota (MN); Permanente Dental Associates in cooperation with Kaiser Permanente Center for Health Research (PDA); and Denmark, Norway, and Sweden (SK).[43] DPBRN dentist practitioner-investigators were recruited through continuing education courses and mass mailings to licensed dentists within the participating regions.

DPBRN dentists also can be characterized by "type of practice," which is categorized as either a solo or small group private practice, a large group practice, or a public health practice. Small practices were defined as those consisting of three dentists or less. Public health practices were defined as those that receive the majority of their funding from public sources.

Analyses of the characteristics of DPBRN dentists and their practice characteristics suggest that while DPBRN dentists have much in common with dentists at large, they also demonstrate substantial diversity within the network in terms of these characteristics.[38,39]

Variable selection

To identify dentists and practice characteristics related to dentists' use of an enamel-based interproximal restorative treatment threshold, explanatory variables were identified. These variables were based on literature related to theoretical models of factors associated with dentists' treatment decisions and dental practice characteristics (see Table 2).[8,43,44] These variables included measures of a dentist's individual characteristics (including year of graduation from dental school, race/ethnicity, and gender), practice setting (practice busyness, waiting time for a restorative dentistry appointment, DPBRN region, and type of practice), patient population (dental insurance coverage, percentage of patients who self-pay, age distribution, and racial/ethnic distribution), and dental procedure characteristics (percentage of patient contact time spent doing restorative procedures each day, percentage of patient

contact time spent doing esthetic procedures each day, percentage of patient contact time spent doing extractions each day, and whether caries risk is assessed as a routine part of treatment planning). A logistic regression model tested the potential contribution of variables that showed significant or near-significant bivariate associations.

Statistical analysis

Data were analyzed using SAS software (version 9.1, SAS Institute, Inc.). A p value of 0.05 was considered statistically significant. Bivariate analyses examined associations between the explanatory variables and decisions for restorative intervention for low and high caries risk individuals. When explanatory variables were categorical, Chi-square tests were used for bivariate analysis; when explanatory variables were continuous, t-tests were used. Using stepwise selection, two logistic regressions were performed to simultaneously examine the effect of an explanatory variable on outcome after adjusting for the effect of other explanatory variables. Due to the multicollinearity of region and type of practice, only the "type of practice" variable was tested in the logistic regression model; the dentists' race/ethnicity was not used in analysis because of small cell sizes. McNemar's test (for testing the marginal equality of paired categorical data) was used to determine if dentists reported different decisions about restoring for the two caries risk scenarios.

Results

Questionnaires were mailed to all eligible dentists (n = 901); 500 (56%) were completed and returned. There were no differences in terms of gender, area of specialty, or years since dental school graduation between the eligible participants who decided to participate and those who did not. Not all dentists responded to all questions; as a result, sample sizes differ in some instances.

Table 2. Percentage of practitioner-investigators who would recommend restorative intervention for interproximal radiographic images in Cases 1–5, based on separate scenarios for low and higher caries risk individuals.

Case	Frequency (%) of low caries risk scenario (n = 500)	Frequency (%) of higher caries risk scenario (n = 499)
1	8 (1.8)	44 (9)
2	194 (39)	332 (66.4)
3	273 (54)	120 (24)
4	24 (5)	2 (0.4)
5	1 (0.2)	1 (0.2)

Table 2 summarizes the percentage of dentists who recommended restorative intervention for each of the case scenarios. A total of 39% of practitioner-investigators reported that they would intervene with a restoration for a patient at low caries risk with a lesion in the inner half of the enamel (Case 2), while 2% of dentists would intervene restoratively even when the lesion was still in the outer half of the enamel (Case 1); however, most dentists (54%) would not intervene unless the lesion was into the outer third of the dentin (Case 3). Conversely, among patients with a higher caries risk, the majority of dentists (75%) reported that they would intervene with a restoration when the lesion was still in the outer or inner half of the enamel (Cases 1 and 2).

According to the survey, 69% of dentists reported that they assess patients' caries risk during part of routine treatment planning. Of these, only 18% (n = 63) use a special form for caries risk assessment. Dentists from the PDA (100%), SK (94%), and MN (93%) regions reported assessing caries risk as part of routine treatment planning significantly more often than dentists from the AL/MS (65%) and FL/GA (63%) regions.

The authors analyzed responses to find associations between the decision to intervene into enamel lesions (combining Cases 1 and 2) or dentin lesions (combining Cases 3, 4, and 5) and the study explanatory variables. Tables 3 and 4 depict how explanatory variables are distributed among those who would recommend restorative intervention (using either caries risk scenario) when the caries lesion was still in the enamel.

No significant differences were found for the following variables: years since graduation from dental school, waiting time for a restorative dentistry appointment, dental insurance coverage, and percentage of patient contact time spent each day doing extractions (for both scenarios, low and higher caries risk individuals). For a low caries risk individual, male dentists would intervene significantly more often in enamel surfaces than female dentists (p = 0.002), while dentists in practices that are "Not busy enough" also would intervene significantly more often in enamel surfaces (p = 0.018).

Table 3. Percentage of DPBRN practitioner-investigators who would recommend restorative intervention for interproximal caries based on radiograph lesion depth for a low caries risk patient, according to dentist and practice characteristics.

	n	Percentage of dentists who would recommend restorative intervention at enamel depth (*n* = 202)	*p* value
Gender of dentist			0.002*
Male	412	43	
Female	88	26	
Practice busyness			0.018*
Too busy to treat all people requesting appointments	53	23	
Provided care to all, but the practice was overburdened	86	36	
Provided care to all, but the practice was not overburdened	267	42	
Not busy enough	78	49	
Region			< 0.001*
AL/MS	290	49	
FL/GA	101	49	
MN	30	20	
PDA	50	8	
SK	29	0	
Type of practice			< 0.001*
SGP	417	48	
LGP	77	9	
PHP	21	0	
Percentage of patients who self-pay			0.2454
0	14	14	
1–30	235	41	
31–50	126	42	
≥51	102	41	
Percentage of patient contact time spent each day doing restorative procedures			0.007
≤50	190	32	
51–80	260	47	
>80	44	39	
Percentage of patient contact time spent each day doing esthetic procedures			0.005*
0	7	0	
1–30	401	37	
31–50	50	56	
>50	23	52	
Whether caries risk is assessed as a routine part of treatment planning			0.018*
Yes	344	38	
No	134	49	

* Statistical significance

Significant differences were found based on DPBRN region ($p < 0.001$); practitioner-investigators from the MN, PDA, and SK regions were less likely to recommend restoring enamel lesions than practitioner-investigators from the AL/MS and FL/GA regions. Significant differences based on type of practice also were evident ($p < 0.001$). Practitioner-investigators who work in large group practices and public health practices were less likely to recommend intervening restoratively on enamel lesions as compared to practitioner-investigators who work in solo or small group private practices.

Regarding dental procedure characteristics, practitioners who spent between 50% and 80% of each day performing restorative procedures ($p = 0.007$), spent 31% or more of their time each day performing esthetic procedures ($p = 0.005$), and did not assess caries risk as a routine part of treatment planning ($p = 0.018$) were more likely to intervene on enamel surfaces than their counterparts. In the logistic regression analysis (see Table 5), only the type of practice ($p < 0.0001$) was significant after adjusting for other explanatory variables. The odds of recommending a restoration in enamel were significantly lower for dentists in large group practices compared to those in small group practices (odds ratio = 0.11, 95% CI = [0.05, 0.23]).

The same pattern held for the bivariate analysis of the decision to intervene into enamel (combining Cases 1 and 2) or dentin (combining Cases 3, 4, and 5) and the study explanatory variables in a higher caries risk scenario (Table 4). Only two exceptions were found: First, no significant difference was found based on the percentage of time spent each day performing

restorative procedures (p = 0.312); second, dentists working in offices that had a higher percent of self-paying patients would intervene more frequently on enamel lesions (p = 0.003).

In the logistic regression analysis (see Table 5), type of practice (p < 0.0001), gender (p = 0.0202), and busyness (p = 0.0215) were significant after adjusting for other explanatory variables. The odds of recommending a restoration in enamel were higher for dentists in small group practices than those in public health practice (OR = 5.49, 95% CI = 1.65, 18.31), higher for male dentists than female dentists (OR = 1.99, 95% CI = 1.11, 3.56), and lower for the highest level of busyness ("Too busy to treat all people requesting appointments") compared to the "Provided care to all but not overburdened" level of busyness (OR = 0.33, 95% CI = 0.17, 0.67).

Discussion

There has been a pronounced change in both the epidemiology and disease pattern of dental caries.[23,24,45] A paradigm shift has occurred since the advent of fluoride, and enamel and dentin lesions that are not cavitated can be arrested through remineralization.[25-27,46] National organizations in the U.S. and studies conducted overseas have provided clinical guidelines; some of these guidelines recommend that prevention should be attempted before any surgical treatment is performed.[47,48] Current expert opinion suggests that restorative intervention is inappropriate for noncavitated lesions.[46] Despite the latest scientific evidence, most DPBRN dentists still chose to intervene for enamel lesions in high caries risk individuals and on outer dentin lesions regardless of the patient's caries risk status.

Table 4. Percentage of DPBRN practitioner-investigators who would recommend restorative intervention for interproximal caries based on radiograph lesion depth for a high caries risk patient, according to dentist and practice characteristics.

	n	Percentage of dentists who would recommend restorative intervention at enamel depth (*n* = 376)	*p* value
Gender of dentist			< 0.001*
Male	413	79	
Female	86	59	
Practice busyness			0.007*
Too busy to treat all people requesting appointments	53	57	
Provided care to all, but the practice was overburdened	84	74	
Provided care to all, but the practice was not overburdened	267	79	
Not busy enough	79	78	
Region			< 0.001*
AL/MS	291	84	
FL/GA	100	86	
MN	30	47	
PDA	50	52	
SK	28	21	
Type of practice			< 0.001*
LGP	76	82	
SGP	407	47	
PHP	16	31	
Percentage of patients who self-pay			0.003*
0	14	36	
1–30	235	77	
31–50	126	79	
≥51	102	73	
Percentage of patient contact time spent each day doing restorative procedures			0.312
≤50	190	74	
51–80	260	78	
>80	43	70	
Percentage of patient contact time spent each day doing esthetic procedures			0.007*
0	7	29	
1–30	400	74	
31–50	50	86	
>50	23	83	
Whether caries risk is assessed as a routine part of treatment planning			< 0.001*
Yes	345	71	
No	135	87	

* Statistical significance

Table 5. Results for the logistic regression related to the percentage of DPBRN practitioner-investigators who would recommend restorative intervention for interproximal caries based on radiograph lesion depth only into the enamel—for low and high caries risk patients—according to dentist and practice characteristics.

Explanatory variable	Low caries risk *p* value*	High caries risk *p* value
Gender of dentist	>0.05	0.0202
Practice busyness	>0.05	0.0215
Region	>0.05	>0.05
Type of practice	<0.0001	<0.0001
Percentage of patients who self-pay	>0.05	>0.05
Percentage of patient contact time spent each day doing restorative procedures	>0.05	>0.05
Percentage of patient contact time spent each day doing esthetic procedures	>0.05	>0.05
Whether caries risk is assessed as a routine part of treatment planning	>0.05	>0.05

* 22 observations were deleted from the logistic regression analysis due to lack of convergence in estimation of model parameters

In the current study, variations in the diagnosis and treatment of dental caries among clinicians were highest when assessing the outer third of dentin.[49,50] According to the literature, the occurrence of cavitation among these types of lesions can range from 20–90%.[51-53]

Although it is possible that respondents could misinterpret the severity of the lesions depicted in the radiographic images, it is unlikely that such misinterpretation could occur differentially by the explanatory variables examined in this study. As a result, the differences in terms of dentists' willingness to intervene restoratively are likely reflections of true differences in their beliefs about the appropriate point in lesion progression for initiating such treatment.

Studies have reported that restorative thresholds used by dentists may correlate poorly with the number of positive treatment decisions actually made.[54] Dentists' perceptions of dental caries depth resulting from a review of bitewing radiographs play a major but variable role in their restorative decisions for interproximal tooth surfaces.[6,7,55] The results of the current study should be interpreted with caution, as they rely on the information provided by dentists at the time that they answered the survey and not at the actual time of treatment.

The different responses regarding the restorative treatment threshold also could relate to any of several other reasons. The most prominent difference regarding restorative treatment threshold was related to the type of practice and the DPBRN region. Dentists participating in a solo or small group private practice were more likely to intervene surgically when lesions were present in enamel but had not yet penetrated into the dentin than those dentists who participated in large group practices or public health practices. In solo or small group private practices, operational and management considerations may be stronger than in large group practices and public health practices and may exert more influence on treatment choices as a result. If practice revenues and costs are functions of the number and type of procedures being done, practices that depend entirely on these variables may be more likely to endorse procedures that incur higher fees. Therefore, dentists participating in this type of practice may feel encouraged to restore enamel lesions that otherwise could be treated with preventive management. Most of the dentists in the AL/MS and FL/GA regions are solo or belong to small group private practices, while dentists participating in the MN and PDA regions belong primarily to large group practices, such as the Health Partners Dental Group and Permanente Dental Associates, both of which have a fixed base salary and annual individual incentive programs.

By comparison, while dentists in large group practices may have production or revenue incentives, these are not their main source of income; as a result, these dentists do not rely entirely on reimbursement based on the number of procedures and may feel less of a need to intervene at the earliest stage of the disease process, when the condition might be reversed. Additionally, dentists participating in large group practices might be in an environment in which the assessment of caries risk and standardization of diagnosis and treatment of interproximal caries is more consistent for all

dentists in the group. The current study corroborates this thought by showing that dentists from the MN and PDA regions assessed caries risk significantly more often than dentists from the AL/MS and FL/GA regions.

The current study showed that dentists who recommended restorative treatment more often on enamel surfaces were those who belonged to busier practices and to practices which spent higher percentages of time each day performing restorative and esthetic procedures. As mentioned earlier, if revenue is posed solely as a function of the number and type of procedures being done, busier practices and those that place significant emphasis on restorative procedures will most likely treat all types of lesions, including those that otherwise could be managed with less costly treatment.

Dentists in Scandinavia chose not to restore lesions that were limited to enamel; restorative treatment was predominantly recommended for surfaces that involved dentin; other studies in Scandinavia are consistent with these findings.[56,57] In Scandanavia, current treatment strategy is based on diagnosis of caries activity and assessment of the actual caries risk.[58] Only in the last 15 years has this concept been introduced in the U.S.[59,60] Scandinavian dental practices also have restrictive criteria for when the first restoration should be placed; as a result, more Scandinavian studies have demonstrated successful monitoring of interproximal enamel lesions.[10,22,61] Approximately 50% of participating DPBRN practices from the SK region are subsidized by the public health system. The government is involved in health management in some Scandinavian regions and prevention is promoted extensively to the public at large.[48,62] With easier access to care, the recall frequency by Scandinavian patients is more predictable; as a result, Scandinavian dentists may face fewer challenges when monitoring initial lesions.

The current study shows that practitioner-investigators who do not routinely assess a patient's caries risk were more likely to intervene on enamel lesions. These dentists may approach a carious lesion as a separate entity and not as part of a disease process. The literature suggests extensively that the cure for caries does not rely on placing a restoration but rather on patient education and individual assessment of caries risk, which may affect the environment of this multi-factorial disease.[63,64] Treatment plans should be individualized and based on the patient's caries risk. Patients must be educated regarding dietary and oral health habits.

Remineralization is a dynamic process. It can occur only if adequate time has passed between the cycles of acid challenge; as a result, it takes time to remineralize an active caries lesion. If patients do not comply with the dentist's recommendations for their individual treatments, the dentist might feel less inclined to monitor these active caries lesions over time. Despite the validation of nonsurgical treatment for noncavitated lesions, the implementation of research into clinical practice has been a slow process. It is estimated that only 14% of science validated by the literature enters daily clinical practice and that this process takes an average of approximately 17 years.[65]

Conclusion

Among dentists, restorative treatment thresholds based on radiographic images varied substantially. Most dentists would choose to restore lesions that were within the enamel surface for a patient who is at high risk for caries.

Dentists' decisions to intervene surgically in the caries process differ, depending on the patient's caries risk level. For a scenario involving a high caries risk individual, practice busyness, type of practice model, and the dentist's gender were significant factors when deciding to perform surgical intervention. However, for a case scenario involving a low caries risk individual, type of practice model was the only significant factor when deciding to perform surgical intervention.

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