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Discordance between presumed standard of care and actual clinical practice: the example of root canal treatment in the National Dental Practice-Based Research Network

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ABSTRACT

Objectives: Use of a rubber dam during root canal treatment is considered the standard of care because it enhances patient safety and optimizes the odds of successful treatment. Nonetheless, not all dentists use a rubber dam, creating a disconnect between presumed standard of care and what is actually done in clinical practice. Little is known about dentists' attitudes toward use of the rubber dam in their practices. The objectives were to: (1) quantify these attitudes; and (2) test the hypothesis that specific attitudes are significantly associated with rubber dam use.

Setting: National Dental Practice-Based Research Network (NationalDentalPBRN.org).

Participants: 1,490 network dentists.

Outcome measures: Dentists completed a questionnaire about their attitudes toward rubber dam use during root canal treatment. Three attitude scales comprised 33 items that used a 5-point ordinal scale to measure beliefs about effectiveness, inconvenience, ease of placement, comparison to other isolation techniques, and patient factors. Factor analysis, cluster analysis, and multivariable logistic regression analyzed the relationship between attitudes and rubber dam use.

Results: All items had responses at each point on the 5-point scale, with an overall pattern of substantial variation across dentists. Five attitudinal factors and four clusters were identified. These factors and clusters were strongly associated with rubber dam use.

Conclusions: General dentists have substantial variation in attitudes about rubber dam use, which is significantly associated with rubber dam use. These attitudes explain why there is substantial discordance between presumed standard of care and actual practice.

Strengths and limitations of this study

- Large national study of dentists with a diverse range of dentist characteristics, practice types, and patient populations served
- Detailed assessment of attitudes about specific clinical treatment that speaks to whether actual clinical practice conforms to a presumed standard of care
- Single point in time based on dentist self-report

BACKGROUND

Routinized attention to patient safety has gradually but systematically permeated health care, from the individual clinician, to health care teams, to health care systems at large.[1-4] This is because patient safety is considered a fundamental aspect of health care and because the role of malpractice claims in health care costs has evolved.[5-8] In addition to causing no harm, the competent clinician is generally regarded as one who provides care consistent with current scientific evidence and the standard of care. Although this summary applies to all fields of medicine, including dental medicine, the dental profession nonetheless provides an example in which clinicians can readily preclude an adverse patient safety event, and optimize the odds of successful treatment, yet choose not to do so.

The example has to do with root canal treatment. To adequately disinfect the root canal system, the dentist must avoid contamination by bacterial sources, such as the patient's own saliva. On rare occasions patients have ingested or aspirated the small instruments required to clean the canals, resulting in injury. If the dentist places a rubber dam around the tooth during this treatment, then the risk of saliva contamination is reduced almost to zero and the risk of ingestion or aspiration is eliminated entirely. Because a rubber dam ensures patient safety and optimizes the odds of treatment success, its use during all root canal treatment is considered the standard of care by a professional consensus of the American Association of Endodontists (root canal specialists)[9] and general dentists. Technically, the standard of care is decided by the legal system on a case-by-case basis.[10-12] However, courts usually rely on a professional consensus about what a reasonable dentist would do in a similar circumstance. Endodontic claims are among the most frequently filed malpractice claims in dentistry.[13-15] In instances where a patient has ingested or aspirated an instrument, a finding of negligence by the offending dentist would be typical.

Nonetheless, use of a rubber dam during all root canal treatment is not ubiquitous. We previously reported from this study that less than half of United States general dentists always use a rubber dam during root canal treatment.[16] Other studies also have documented sub-optimal use.[17,18] Some dentists

who do not use a rubber dam use small cotton rolls to help isolate the tooth even though this may not do an adequate job of preventing saliva contamination and offers no protection against patient injury. Some have advocated the use of other isolation methods, such as an intraoral suctioning and retraction device called Isolite®,[19] although its use can only offer partial protection. Therefore, there is a discordance or "disconnect" in the dental profession between the presumed standard of care and what is done in actual clinical practice.

Unfortunately, little is known about the attitudes that general dentists have about rubber dam use and other isolation methods, and whether these attitudes are related to rubber dam use. Therefore, our objectives were to: (1) quantify these attitudes; and (2) test the hypothesis that these attitudes are significantly associated with whether the dentist uses a rubber dam during root canal treatment, with other dentist and practice characteristics already taken into account.

METHODS

Dentists in the network provide an opportunity to better understand the services that dental practitioners provide. The network is a consortium of dental practices and organizations focused on improving the scientific basis for clinical decision-making.[20] Many details about the network are publicly available.[21]

Enrollment Questionnaire

The applicable network Institutional Review Boards approved the study; participants provided informed consent after receiving a full explanation of the nature of the procedures. As part of the network enrollment process, practitioners complete an Enrollment Questionnaire that describes characteristics about themselves and their practice(s). Questionnaire items, which had documented test/re-test reliability, were taken from our previous work in a PBRN study of dental care and a network that ultimately led to the National Dental PBRN.[22,23] A copy of the questionnaire is publicly available.[24]

Isolation Techniques questionnaire and its administration

After confirming on the questionnaire that the respondent is a general dentist and does at least one root canal treatment each month, attitudes were measured in: (1) a section that contained 21 "agreement" statements about how strongly one agrees with certain statements, the first 12 of which examined beliefs about the effectiveness of a rubber dam, followed by nine statements about potential problems when using a rubber dam; and (2) 12 "difficulty" statements about how difficult certain root canal treatment practices are. Good test/re-test reliability of these items has been reported previously.[16] A copy of the full questionnaire is publicly available.[25] Qualitative comments were received as a result of including an item at the end of the questionnaire that asked "Is there anything else you think we should know about how you use isolation methods during root canal treatment?", complementing the quantitative findings by providing nuanced information. Comments were received from 678 of the 1491 participants.

We have reported previously details about the survey administration.[16] Briefly, 1,876 dentists who reported on the Enrollment Questionnaire that they were a general dentist; currently practicing/seeing patients; performing at least some root canal treatment; and at least "limited" or "full" network participants were invited to complete the Isolation Techniques questionnaire.

Statistical methods

Analyses were done using SPSS.[26] The main outcomes of interest were the frequency of use of different types of isolation techniques, with attitudes as the key predictors. A principal components analysis with orthogonal rotation was conducted separately for the 21 agreement statements and for the 12 difficulty questions as initial examination and potential factor structure, which supported the existence of multiple attitude dimensions. Items deemed appropriate from each scale were subsequently combined and a final principal components analysis was performed. Principal components were rotated to achieve an

orthogonal simple structure and factor regression scores were saved. Factor loadings of .50 and greater were used for interpretation. The Kaiser-Myer-Okin statistic measured sampling adequacy for factor analysis.[27]

Using multivariable logistic regression, factor regression scores were used to examine the relationship between the dentist's attitudes about isolation techniques and the whether these techniques were used. In addition, cluster analysis was performed using factor regression scores to identify homogenous subgroups who have similar attitudes about rubber dam as an isolation technique. An advantage of this approach is that decisions are made using a combination of attitudes and beliefs, and cluster membership is determined by each dentist's set of attitudes. Ward's clustering method, with squared Euclidean distances as the similarity measure, was used to be sensitive to differences in elevation as well as profile shape.[28]

RESULTS

Details on eligibility, response rates, differences between participants and non- participants, and characteristics of participants have been previously reported.[16]

Frequency of use of rubber dam and other isolation techniques

Only 47% reported always using a rubber dam during root canal treatment. Cotton rolls are used at least sometimes by 47% of participants and all the time by 12%. Isolite® was used by 8% (n=126). A total of 3% (n=39) used a method other than rubber dam, cotton roll, or Isolite®. Only 5% (n=70) use no method of isolation. Based on the frequency distributions for each isolation technique, the following cut points were used during subsequent model testing: rubber dam use all the time (n=697, 47% of dentists); and cotton roll use at least 50% of the time (n=283, 19% of dentists). Because of its infrequent use, Isolite® use was not modeled.

Distribution of attitudes items and factor analysis

The wording of the attitude questions is provided in Table 1. The distributions of responses to each item are publicly available.[29] With the exception of question 23 (skew=-1.73, kurtosis=3.0) and question 32 (skew=-2.92, kurtosis=11.43), responses to the agreement statements had skew and kurtosis of less than ± 2; 16 of 21 were ±1. Skew and kurtosis for the difficulty questions were all within ±1 and ranged from -.66 to 0.80 for skew and -.33 to .79 for kurtosis.

The Kaiser-Myer-Okin Measure of Sampling Adequacy was .910 for the agreement statements and .896 for the difficulty questions; these are very high. The 21 agreement statements formed 5 factors with an eigenvalue of greater than 1.0. The final factor consisted of a single item (Q23 – adequate training in dental school) loading higher than .40. The other four factors had at least three items with loadings of .50 or greater. The 12 difficulty questions formed 3 factors, each with four items with loadings of .50 or greater.

Items from both scales were then combined and principal components analysis of the final pool of 31 items was done. Items Q23 and Q32 were not included because of their skewness and kurtosis. The Kaiser-Myer-Okin Measure of Sampling Adequacy was .936. The rotated solution accounted for 62% of the total variance and resulted in a 5-factor solution based on eigenvalues greater than one criterion and scree test. Factors and factor loadings are presented in Table 1. The first factor comprised 10 items from the attitude agreement scale and represented “rubber dam is effective”, accounting for 18% of the variance. The second factor comprised 10 items predominantly from the agreement attitude scale and represented “using a rubber dam is inconvenient and time consuming”, accounting for 13% of the variance. The third factor comprised primary loadings from four items and two secondary loadings of items from the difficulty attitude scale and represented “rubber dam is easy to place”, accounting for 12% of the variance. The fourth factor comprised three items from the attitude agreement scale and represented “rubber dam is just as effective as Isolite” and accounted for 10% of the variance. The final factor comprised four items from

Table 1. Factor structure and loadings for attitudes about isolation techniques used during root canal treatment

Question number	Question wording	Factor 1: RD effectiveness	Factor 2: Inconvenient/ time consuming	Factor 3: Ease of placement	Factor 4: RD effectiveness compared to Isolite®	Factor 5: Patient factors
	Agreement items					
24	Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on *anterior* teeth.	-.62				
25	Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on *premolar* teeth.	-.70				
26	Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on *molar* teeth.	-.67				
27	Isolite® is just as effective as the rubber dam when root canals are done on *anterior* teeth.				.91	
28	Isolite® is just as effective as the rubber dam when root canals are done on *premolar* teeth.				.94	
29	Isolite® is just as effective as the rubber dam when root canals are done on *molar* teeth.				.88	
30	Using a rubber dam during root canals reduces the likelihood of infection for patients.	.66				
31	Using a rubber dam during root canals decreases the likelihood of infection for practitioners and office staff.	-.69				
33	Using rubber dams when performing root canals improves treatment effectiveness.	.83				
34	Rubber dams control moisture very well during root canals.	.69				
35	It's very important to use a rubber dam every time a root canal is performed.	.77				
36	Rubber dams tear frequently.		.58			
37	Rubber dams make it easier to perform root canals.	.69				
38	Most dentists I know use	.58				

	rubber dams when performing root canals.					
39	Placing a rubber dam before performing a root canal is time-consuming.		.62			
40	Clamp placement requires the use of additional anesthesia around the gum line when rubber dams are used to perform root canals.		.53			
41	Using rubber dams to perform root canals is inconvenient.		.62			
42	Patients are uncomfortable wearing a rubber dam during root canals.		.60			
43	Maintaining an adequate supply of rubber dams in one's practice is difficult.		.45			
	Difficulty items					
	How hard or easy it for you to …					
44	place a rubber dam to perform a root canal?			.74		
45	place a rubber dam on an *anterior* tooth to perform a root canal?			.77		
46	place a rubber dam on a *premolar* tooth to perform a root canal?			.82		
47	place a rubber dam on a *molar* tooth to perform a root canal?			.65		
48	fit a clamp that is too big, too small, or of awkward size for the tooth?					.68
49	place a rubber dam when you have limited access and visibility of the isolated operating area?					.79
50	place a rubber dam when the patient doesn't have the ability to open his/her mouth very wide?					.73
51	explain to a patient the importance of using a rubber dam to perform a root canal?		-.44			
52	communicate with the patient (as needed) during a root canal when a rubber dam is being used?		-.49			
53	use a rubber dam to perform a root canal with a patient who is claustrophobic, talkative, a gagger, and/or has					.59

	a breathing problem (e.g., COPD)?					
54	get assistance from auxiliary staff to place a rubber dam when needed?		-.45	.44		
55	use a rubber dam to perform a root canal when you have competing demands in your clinic (e.g., other patients are waiting for you to check them after a cleaning)?		-.53	.46		

the difficulty scale and represented "patient factors do not complicate the use of a rubber dam", accounting for 9% of the variance.

Logistic Regression

With the outcome as using a rubber dam all of the time, dentists who more strongly agreed that a rubber dam is effective ($p < .001$), who rated a rubber dam as easy to place ($p < .001$), and who believe that patient factors do not complicate rubber dam use ($p < .001$,) were more likely to use a rubber dam all of the time (Table 2). Dentists who agreed more strongly that using a rubber dam is inconvenient and time consuming ($p < .001$) or that using rubber dam is just as effective as Isolite®, were less likely to use a rubber dam all of the time (Table 2).

Table 2. Multivariable logistic regression quantifying the relationship between dentists' attitudes and rubber dam use

	Parameter estimate (Standard Error)	p-value	Odds Ratio (95% Confidence Interval of the Odds Ratio)
Attitudes			
Rubber dam effectiveness	1.43 (.11)	< .001	4.17 (3.35 - 5.18)
Inconvenient/time consuming	-0.78 (.08)	< .001	0.46 (0.39 - 0.54)
Ease of placement	0.50 (.08)	< .001	1.65 (1.42 - 1.93)
Rubber dam effectiveness compared to Isolite®	-1.17 (.09)	< .001	0.31 (0.26 - 0.36)
Patient factors	0.43 (.08)	< .001	1.52 (1.31 - 1.76)
Dentist and practice characteristics			
Endodontist in same building	0.46 (.46)	0.32	1.58 (0.65 – 3.87)
Public health practice model (reference is large group practice)	-1.21 (.43)	0.01	0.30 (0.13 - 0.69)
Private practice model (reference is large group practice)	-1.07 (.28)	<.001	0.34 (0.20 - 0.59)
Dentist gender (male)	-0.21 (.18)	0.26	0.81 (0.57 - 1.17)
Decades since dental school graduation	-0.17 (.07)	0.02	0.85 (0.74 - 0.97)
Any additional training since dental school	0.26 (.15)	0.08	1.30 (0.97 - 1.73)
Rural work setting	-0.44 (.20)	0.03	0.64 (0.44 - 0.95)
Does fewer than 10 root canals each month	-0.37 (.16)	0.02	0.69 (0.51 - 0.94)

The outcome of interest is whether or not the dentist uses a rubber dam all of the time during root canal treatment.

The regression is adjusted for differences in dentist gender (female=0, male=1); decades since dental school graduation truncated at 30+ coded (0-9=1, 10-19=2, 20-29=3, 30+=4); additional training since dental school (no training=0, additional=1); practice type (large group practice=0, private practice=1, public health/government/other=1); whether the practice is located in a rural setting (urban/suburban=0, rural=1); whether an endodontist is located in the same building as the practice (no=0, yes=1); and whether the dentist does fewer than 10 RCT each month (10 or more=0, less than 10=1).

The model fit was statistically significant (n= 1445, chi-square = 802.7, $p < .001$ with df=13). Nagelkerke's R^2 of .57. The prediction success overall was 80% (80% for using a rubber dam all the time and 80% for not using the rubber dam all the time).

Cluster Analysis

Examination of differences in potential clusters and inspection of mean factor scores for each cluster, suggested that a four-cluster solution is the most appropriate and interpretable.[29] Mean factor regression scores and frequencies for choice of isolation techniques for each cluster are presented in Tables 3 and 4,

respectively.

Table 3. Factor regression scores for each of the five attitude factors, by cluster.

	Rubber dam effective-ness	Ease of placement	Inconvenient/ time consuming	Compared to Isolite®	Patient factors
Cluster 1: RD not effective and not easy to place (n=252)	-1.50	-.44	.18	.25	-.35
Cluster 2: RD moderately effective but inconvenient/time consuming (n=302)	-.08	.14	.75	.63	-.14
Cluster 3: RD is effective but inconvenient/time consuming and not easy to place (n=504)	.42	-.31	-.45	.45	.25
Cluster 4: RD is effective and much more so than Isolite® (n=401)	.40	.19	-.10	-1.20	.09

n=1,459. Factor regression scores are standardized scores with an overall sample mean=0 and SD=1. Mean factor regression scores for each cluster represent the difference between each cluster's mean and the overall mean of the sample. For example, the -1.50 score for cluster 1 on "Rubber dam effectiveness" is interpreted as 1.5 standard deviations less than the overall mean for that factor. The advantage over scale scores is that factor regression scores can be compared to each other directly.

Table 4. Frequency of use of isolation techniques, by cluster.

	% who use RD all of the time	% who use cotton rolls at least 50% of the time	% use Isolite®
Cluster 1: RD not effective and not easy to place (n=252)	7	61	11
Cluster 2: RD moderately effective but inconvenient/time consuming (n=302)	39	24	11
Cluster 3: RD is effective but inconvenient/time consuming and not easy to place (n=504)	44	8	11
Cluster 4: RD is effective and much more so than Isolite® (n=401)	82	3	1

The first cluster comprised 252 dentists who held attitudes that rubber dam use is not effective and not easy to place. They also held the attitude that perceived patient factors "do complicate" the use of a rubber dam. This group was least likely to use a rubber dam all the time (7% use a rubber dam all of the time) and the most likely to use a cotton roll at least half the time (61% of the cluster). The second cluster comprised 302 dentists who had the highest agreement on statements that rubber dam use is inconvenient and time consuming. They were near the overall mean for whether rubber dam is effective and easy to place. They also held the belief that Isolite® is just as effective as rubber dam. As a group, they were second least likely to use a rubber dam (39% use a rubber dam all of the time). The third cluster comprised 504 dentists. This group was most likely to agree with statements that rubber dam use was inconvenient and time consuming and held the attitude that rubber dam use is effective. Nevertheless, they did believe that rubber dam can be difficult to place, but that patient factors were not the issue. This group used the rubber dam at similar frequencies to the second group (44% use a rubber dam all of the time) and were not frequent users of a cotton roll. The fourth cluster comprised 401 general dentists, who held the attitude that rubber dam use is effective and were close to the overall mean on whether rubber dam use was inconvenient and time consuming. This was the group who most strongly disagreed with statements that Isolite® is just as effective as rubber dam. As a group, they almost exclusively used a rubber dam for root canal treatment (82% use a rubber dam all of the time) and almost never used Isolite®.

DISCUSSION

Although almost all (96%) agreed that using a rubber dam reduces the potential for ingestion or aspiration, only 78% agreed that rubber dam use improves treatment effectiveness. This latter percentage is consistent with the minority (from 6%-24%, depending on the question, for questions 24-29) who agreed that cotton roll or Isolite® use is just as effective as a rubber dam. In one of the few studies ever to evaluate dentist attitudes toward rubber dam use, a study of 300 Irish dentists found that only 42% agreed with the

statement “Root canal fillings placed without rubber dam isolation are as successful as when rubber dam isolation is used”.[31] A study of final-year dental students at two British dental schools observed that 10% agreed with “Root canal fillings placed without rubber dam are as successful as those isolated with rubber dam” and 68% agreed with “Rubber enables a higher clinical standard to be achieved”.[32] Unfortunately, neither of these two studies related the attitudes to whether or not the dentist reported actually using a rubber dam or intended to. A 2009 review of the literature concluded that lack of patient acceptance and the time required to apply the rubber dam were the most common reasons.[33] The same review also concluded that patient acceptance is actually very high and can be influenced substantially by the enthusiasm and experience of the dentist and dental assistant.[33] We are aware of no United States dental school that does not require use of a rubber dam during root canal treatment, regardless of whether the treatment is being done by a student, resident, or faculty member. Our sense is that schools consider a tooth inappropriate for root canal treatment if a rubber dam cannot be placed; in those cases, root canal treatment is not done and the tooth is referred for extraction.

We conclude from the results in Tables 2-4 that several key factors are associated with rubber dam use. Attitudes about rubber dam use for treatment effectiveness and patient safety, either alone or in comparison to Isolite®, seem to be the main factors, with additional contributions from inconvenience, ease of use, and patient factors. These results make it clear that there is not a profession-wide consensus about the importance of rubber dam use. Regarding the patient safety issue, the profession may benefit from an effort similar to what has occurred in surgery regarding “never events”,[4] which like patient ingestion or aspiration of root canal treatment instruments are rare, but nonetheless are so egregious that they warrant a routinized approach to their avoidance. Regarding treatment effectiveness, the evidence that rubber dam use improves long-term treatment effectiveness is limited,[34,35] but is it clear that to adequately disinfect the root canal system, the dentist must avoid contamination by bacterial sources, such as from the patient’s own saliva.

Although 47% of network dentists reported using a rubber dam all of the time, 16% reported using it from 90%-99% of the time. It is possible that this latter group of dentists begins with an intention to use the rubber dam for a given patient, but decides not to if they have trouble placing it or if the patient expresses a strong desire not to have a rubber dam placed. This would be consistent with the approximate percentage of dentists who agreed or strongly agreed with the difficulties queried in the Factor 5 (patient factors) items. For this reason, we repeated the multivariable logistic regression in Table 2, except that the outcome of interest was rubber dam use of 90% or more, instead of all the time (results not shown, but publicly available as Table A2 [29]). However, the substantive conclusions were the same.

This study does have certain limitations, and conclusions made from it should take these into account.[16] Although network practitioners have much in common with dentists at large,[36,37] it is possible that their root canal treatment procedures are not representative of dentists at large. Additionally, network members are not recruited randomly, so factors associated with network participation (e.g., an interest in clinical research) may make network dentists unrepresentative of dentists at large. While we cannot assert that network dentists are entirely representative, we can state that they have much in common with dentists at large, while also offering substantial diversity in these characteristics.[16]

Results from this study can inform a next-stage intervention targeted to network members and potentially to the dental profession at large. Dissemination and scale-up approaches could be used which are targeted to practitioners who report no or low rubber dam use.[38] These approaches have been used successfully in the network regarding treatment of early dental decay.[39-41] The often-lamented "research-to-practice gap" refers to the delay between what research evidence suggests should be happening in routine clinical practice, and what is actually happening. The results in this study suggest that the gap relevant to rubber dam use is a circumstance in which knowledge is available and providers are aware of it, but they have not yet implemented the recommended changes. Qualitative comments provided at the end of the questionnaire complemented the quantitative findings by providing nuanced information. For

example, practitioners are generally well aware of the potential for adverse patient safety events, the potential for reduction in treatment effectiveness, and the presumed standard of care. However, their retort is oftentimes their own individual clinical experience that they have not had these problems, in concert with their experience that rubber dam can be difficult to place or not wanted by patients. Other practitioners who routinely use a rubber dam suggested that rubber dam placement is simple and that reports by other practitioners can be ascribed to insufficient training during dental school or not having dental assistants available during dental school or residency, leading them to an early but unwarranted conclusion that rubber dam use is not acceptable to patients, too difficult, or not necessary.

List of abbreviations

PBRN: practice-based research network

RD: rubber dam

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Author contributors

GHG, PDE, and PLR contributed to study design and questionnaire testing. JLR and GHG conducted the analysis and review of the data and drafted the initial version of the manuscript. All authors were involved in the intellectual content and drafting of the manuscript, read and approved the final manuscript, and agree to be accountable for all aspects of the work.

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REFERENCES

1. Bishop A, Fleming M. Patient safety and engagement at the frontlines of healthcare. *Healthc Q* 2014;17 Spec No:36-40.
2. Berkowitz RL. Of parachutes and patient care: a call to action. *Am J Obstet Gynecol* 2011;205(1):7-9.
3. Galbraith RM, Holtman MC, Clyman SG. Use of assessment to reinforce patient safety as a habit. *Qual Saf Health Care* 2006;15(Suppl 1):i30-i33.
4. Mehtsun WT, Ibrahim AM, Diener-West M, Pronovost PJ, Makary MA. Surgical never events in the United States. *Surgery* 2013;153(4):465-472.
5. Mello MM, Studdert DM, Kachalia A. The medical liability climate and prospects for reform. *JAMA* 2014;312(20):2146-2155.
6. Wallace E, Lowry J, Smith SM, Fahey T. The epidemiology of malpractice claims in primary care: a systematic review. *BMJ Open* 2013;3(7):e002929.
7. Oyebode F. Clinical errors and medical negligence. *Med Princ Pract* 2013;22(4):323-333.
8. Institute of Medicine (US) Committee on Quality of Health Care in America; Kohn LT, Corrigan JM, Donaldson MS, editors. To Err is Human: Building a Safer Health System. Washington (DC): National Academies Press (US); 2000.
9. American Association of Endodontists. AAE Position Statement: Dental Dams. Available at http://www.aae.org/uploadedfiles/clinical_resources/guidelines_and_position_statements/dentaldamstatement.pdf. Accessed August 14, 2015.
10. McMurtrie L. Setting the legal standard of care for treatment and evidence-based medicine: a case study of antenatal corticosteroids. *J Law Med* 2006;14(2):220-227.
11. Kozlick D. Clinical practice guidelines and the legal standard of care: warnings, predictions, and interdisciplinary encounters. *Health Law J* 2011;19:125-151.

12. Brenner LH, Brenner AT, Awerbuch EJ, Horwitz D. Beyond the standard of care: a new model to judge medical negligence. *Clin Orthop Relat Res* 2012;470(5):1357-1364.
13. Givol N, Rosen E, Taicher S, Tsesis I. Risk management in endodontics. *J Endod* 2010;36(6):982-984.
14. Perea-Pérez B, Labajo-González E, Santiago-Sáez A, Albarrán-Juan E, Villa-Vigil A. Analysis of 415 adverse events in dental practice in Spain from 2000 to 2010. *Med Oral Patol Oral Cir Bucal* 2014;19(5):e500-e505.
15. Webber J. Risk management in clinical practice. Part 4. Endodontics. *Br Dent J* 2010;209(4):161-170.
16. Lawson NC, Gilbert GH, Funkhouser E, Eleazer PD, Benjamin PL, Worley DC, National Dental PBRN Collaborative Group. General dentists' use of isolation techniques during endodontic procedures: from the National Dental Practice-Based Research Network. *J Endod* 2015;41(8):1219-1225.
17. Savani GM, Sabbah W, Sedgley CM, Whitten B. Current trends in endodontic treatment by general dental practitioners: report of a United States national survey. *J Endod* 2014;40(5):618-624.
18. Ahmad IA. A Rubber dam usage for endodontic treatment: a review. Int Endod J 2009;42(11):963–972.
19. Wahl P, Andrews T, Isolation: a look at the differences and benefits of rubber dam and Isolite. *Endo Practice* 2010;(3)2:52-55.
20. Gilbert GH, Williams OD, Korelitz JJ, Fellows JL, Gordan VV, Makhija SK, Meyerowitz C, Oates TW, Rindal DB, Benjamin PL, Foy PJ for the National Dental PBRN Collaborative Group. Purpose, structure and function of the United States National Dental Practice-Based Research Network. *J Dent* 2013;41(11):1051-1059.
21. The National Dental Practice-Based Research Network, the nation's network. Available at: "http://nationaldentalpbrn.org/". Accessed August 14, 2015.
22. The Florida Dental Care Study. Available at: "http://nersp.nerdc.ufl.edu/~gilbert/". Accessed August 14, 2015.

23. Gilbert GH, Richman JS, Gordan VV, Rindal DB, Fellows JL, Benjamin PL, Wallace-Dawson M, Williams OD, DPBRN Collaborative Group. Lessons learned during the conduct of clinical studies in the Dental PBRN. *J Dent Educ* 2011;75(4):453-465.

24. Enrollment Page, National Dental PBRN. Available at: http://nationaldentalpbrn.org/enrollment.php. Accessed August 14, 2015.

25. Study Results Page, National Dental PBRN, Isolation Techniques Used When Performing Root Canal Treatment section. Available at http://nationaldentalpbrn.org/study-results.php. Accessed August 14, 2015. The questionnaire is directly accessible at http://nationaldentalpbrn.org/tyfoon/site/fckeditor/file/IsolationTechniquesQuestionnaire-2013-12-27-V10%200(Clean)_Annotation.pdf.

26. IBM SPSS Statistics 22 Documentation. IBM Software Group, Chicago, IL. Available at: http://www-01.ibm.com/support/docview.wss?uid=swg27038407. Accessed August 14, 2015.

27. Cerny, CA, Kaiser, HF. 1977. A study of a measure of sampling adequacy for factor-analytic correlation matrices. *Multiv Behav Res* 12(1):43-47.

28. Overall JE, Gibson JM, Novy DM. Population recovery capabilities of 35 cluster analysis methods. *J Clin Psychol* 1993;49:459-470.

29. Study Results Page, National Dental PBRN. Available at http://nationaldentalpbrn.org/study-results.php

30. Milligan GA, Cooper MC. An examination of procedures for determining the number of clusters in a data set. *Psychometrika* 1967;50:159-179.

31. Lynch CD, McConnell RJ Attitudes and use of rubber dam by Irish general dental practitioners. *Int Endod J* 2007;40(6):427-432.

32. Mala S, Lynch CD, Burke FM, Dummer PMH. Attitudes of final year dental students to the use of rubber dam. *Int Endo J* 2009;42(7):632-638.

33. Ahmad IA. A Rubber dam usage for endodontic treatment: a review. *Int Endod J* 2009;42(11):963–972.

34. Lin PY, Huang SH, Chang HJ, Chi LY. The effect of rubber dam usage on the survival rate of teeth receiving initial root canal treatment: a nationwide population-based study. *J Endod* 2014;40(11):1733-1737.

35. Goldfein J, Speirs C, Finkelman M, Amato R. Rubber dam use during post placement influences the success of root canal-treated teeth. *J Endod* 2013;39(12):1481-1484.

36. Makhija SK, Gilbert GH, DB Rindal, PL Benjamin, JS Richman, DJ Pihlstrom, V Qvist, DPBRN Collaborative Group. Dentists in practice-based research networks have much in common with dentists at large: evidence from the Dental PBRN. *Gen Dent* 2009;57(3):270-275.

37. Makhija SK, Gilbert GH, Rindal DB, Benjamin PL, Richman JS, Pihlstrom DJ, Qvist V, DPBRN Collaborative Group. Practices participating in a dental PBRN have substantial and advantageous diversity even though as a group they have much in common with dentists at large. *BMC Oral Health* 2009;9(1):26-35.

38. Brownson RC, Colditz GA, Proctor EK. Dissemination and implementation research in health: translating science to practice. New York: Oxford University Press, Inc.; 2012.

39. Gilbert GH, Richman JS, Qvist V, Pihlstrom DJ, Foy PJ, Gordan VV. Change in stated clinical practice associated with participation in the Dental Practice-Based Research Network. *Gen Dent* 2010;58:520-528.

40. Gilbert GH, Gordan VV, Funkhouser EM, Rindal DB, Fellows JL, Qvist V, Anderson G, Worley D. Caries treatment in a dental practice-based research network: movement toward stated evidence-based treatment. *Community Dent Oral Epidemiol* 2012;41:143-153.

41. Rindal DB, Flottemesch TJ, Durand EU, Godlevsky OV, Schmidt A, Gesko DS, Gilbert GH, National Dental PBRN Collaborative Group. Practice change toward better adherence to evidence-based treatment of early dental decay in the National Dental PBRN. *Impl Sci* 2014;9:177.

APPENDIX

The purpose of this appendix is to make certain information directly accessible to the reviewers in a single document.

This Appendix will not appear in the published version of the manuscript.

The typical reader will have access to this Appendix via http://nationaldentalpbrn.org/study-results.php, "Isolation Techniques..." section.

Table A1. Mean, standard deviation and frequency distribution for each questionnaire item used to measure attitudes toward RCT isolation methods

			% (n) responses				
Question number	**Question wording**	**Item mean (S.D.) [a] score**					
	Agreement items [b]		Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
23	I received sufficient knowledge and training in dental school on how to effectively place a rubber dam prior to performing a root canal.	4.28 (0.96)	3 (47)	4 (60)	4 (66)	38 (568)	50 (746)
24	Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on *anterior* teeth.	3.68 [d] (1.30)	36 (540)	26 (383)	14 (206)	18 (265)	6 (94)
25	Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on *premolar* teeth.	4.04 [d] (1.14)	47 (692)	28 (418)	12 (172)	11 (157)	3 (48)
26	Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on *molar* teeth.	4.42 [d] (0.93)	64 (954)	22 (321)	8 (124)	4 (60)	2 (27)
27	Isolite™ is just as effective as the rubber dam when root canals are done on *anterior* teeth.	3.31 [d] (1.04)	18 (269)	15 (218)	51 (753)	11 (167)	5 (67)
28	Isolite™ is just as effective as the rubber dam when root canals are done on *premolar* teeth.	3.40 [d] (1.03)	20 (301)	17 (247)	49 (728)	10 (143)	4 (56)
29	Isolite™ is just as effective as the rubber dam when root canals are done on *molar* teeth.	3.56 [d] (1.03)	26 (377)	17 (255)	48 (703)	6 (95)	3 (44)
30	Using a rubber dam during root canals reduces the likelihood of infection for patients.	3.85 (1.04)	2 (31)	10 (146)	20 (301)	37 (546)	31 (463)
31	Using a rubber dam during root canals decreases the likelihood of infection for practitioners and office staff.	3.12 (1.09)	7 (101)	22 (333)	35 (522)	24 (355)	12 (176)
32	Using a rubber dam when performing root canals reduces the potential for swallowed or aspirated dental items.	4.70 (0.63)	1 (14)	1 (6)	2 (31)	21 (317)	75 (1,119)
33	Using rubber dams when performing root canals improves treatment effectiveness.	4.15 (1.01)	2 (30)	7 (97)	13 (198)	31 (456)	47 (706)
34	Rubber dams control moisture very well during root canals.	4.24 (0.83)	1 (14)	4 (55)	8 (125)	44 (654)	43 (638)
35	It's very important to use a rubber dam every time a root canal is performed.	3.89 (1.25)	5 (78)	14 (203)	12 (184)	24 (363)	44 (657)
36	Rubber dams tear frequently.	3.09 [d] (1.01)	4 (61)	30 (440)	24 (363)	37 (549)	5 (73)

37	Rubber dams make it easier to perform root canals.	3.93 (1.10)	3 (45)	10 (150)	15 (227)	34 (503)	38 (561)
38	Most dentists I know use rubber dams when performing root canals.	3.69 (1.06)	3 (41)	13 (189)	22 (321)	39 (577)	24 (358)
39	Placing a rubber dam before performing a root canal is time-consuming.	3.27 [d] (1.11)	12 (174)	40 (588)	16 (244)	28 (421)	4 (58)
40	Clamp placement requires the use of additional anesthesia around the gum line when rubber dams are used to perform root canals.	2.83 [d] (1.07)	5 (68)	30 (440)	17 (257)	42 (618)	7 (103)
41	Using rubber dams to perform root canals is inconvenient.	3.44 [d] (1.19)	20 (293)	37 (551)	17 (248)	21 (307)	6 (87)
42	Patients are uncomfortable wearing a rubber dam during root canals.	2.95 [d] (1.10)	6 (91)	30 (452)	25 (366)	30 (439)	9 (138)
43	Maintaining an adequate supply of rubber dams in one's practice is difficult.	4.35 [d] (0.75)	49 (726)	40 (592)	10 (143)	1 (14)	1 (11)
	Difficulty items [c]		Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy
	How hard or easy it for you to …						
44	place a rubber dam to perform a root canal?	3.72 (0.86)	1 (9)	7 (109)	30 (441)	45 (663)	18 (264)
45	place a rubber dam on an *anterior* tooth to perform a root canal?	4.01 (0.86)	1 (8)	5 (72)	18 (273)	45 (675)	31 (458)
46	place a rubber dam on a *premolar* tooth to perform a root canal?	4.02 (0.81)	1 (4)	4 (66)	17 (251)	50 (740)	29 (424)
47	place a rubber dam on a *molar* tooth to perform a root canal?	3.51 (0.99)	3 (41)	14 (207)	27 (398)	42 (620)	15 (215)
48	fit a clamp that is too big, too small, or of awkward size for the tooth?	2.52 (0.87)	8 (116)	48 (706)	32 (476)	10 (149)	3 (39)
49	place a rubber dam when you have limited access and visibility of the isolated operating area?	2.16 (0.86)	20 (291)	54 (802)	19 (278)	6 (96)	1 (19)
50	place a rubber dam when the patient doesn't have the ability to open his/her mouth very wide?	1.92 (0.72)	27 (399)	57 (853)	13 (194)	2 (36)	0 (3)
51	explain to a patient the importance of using a rubber dam to perform a root canal?	3.91 (0.85)	1 (12)	4 (62)	23 (345)	47 (693)	25 (374)
52	communicate with the patient (as needed) during a root canal when a rubber dam is being used?	3.45 (0.98)	2 (36)	15 (227)	30 (443)	40 (589)	13 (191)

53	use a rubber dam to perform a root canal with a patient who is claustrophobic, talkative, a gagger, and/or has a breathing problem (e.g., COPD)?	2.13 (0.91)	26 (380)	46 (687)	19 (281)	8 (126)	1 (11)
54	get assistance from auxiliary staff to place a rubber dam when needed?	3.49 (0.97)	3 (44)	12 (181)	31 (467)	40 (590)	14 (204)
55	use a rubber dam to perform a root canal when you have competing demands in your clinic (e.g., other patients are waiting for you to check them after a cleaning)?	3.33 (1.01)	3 (50)	16 (243)	38 (570)	28 (417)	14 (206)

[a] S.D.: standard deviation of the mean

[b] The 21 "agreement" attitude questions asked how strongly respondents agree with the statement, using these response categories: 1=strongly disagree; 2=disagree; 3=neither agree nor disagree; 4=agree; 5=strongly agree.

[c] The 12 "difficulty" attitude questions asked about how difficult certain RCT practices are, using these response categories: 1=very hard; 2=hard; 3=neither hard nor easy; 4=easy; 5=very easy.

[d] Before calculating the mean scores for these questions, the 1-5 scales were inverted so that a higher score would have a positive correlation with using a rubber dam.

Table A2. Multivariable logistic regression quantifying the relationship between dentists' attitudes about rubber dam use and whether or not they use a rubber dam during root canal treatment 90% of the time or more

	B (SE)	P	Odds Ratio (95% CI)
Rubber dam effectiveness	1.97 (.12)	< .001	7.12 (5.57 – 9.13)
Inconvenient/time consuming	-1.23 (.10)	< .001	0.28 (0.23 – 0.35)
Ease of placement	.81 (.09)	< .001	2.17 (1.92 – 2.74)
Compared to Isolite®	-1.49 (.12)	< .001	0.22 (0.17 - 0.28)
Patient factors	.55 (.10)	< .001	1.74 (1.45 - 2.10)

The regression is adjusted for differences in dentist gender (female=0, male=1); decades since dental school graduation truncated at 30+ coded (0-9=1, 10-19=2, 20-29=3, 30+=4); additional training since dental school (no training=0, additional=1); practice type (large group practice=0, private practice=1, public health/government/other=1); whether the practice is located in a rural setting (urban/suburban=0, rural=1); whether an endodontist is located in the same building as the practice (no=0, yes=1); and whether the dentist does fewer than 10 RCT each month (10 or more=0, less than 10=1).

The model fit was statistically significant (n= 1445, chi-square = 1065.6, $p < .001$ with df=13). Nagelkerke's R^2 of .71. The prediction success overall was 88% (80% for not using the rubber dam $\geq$ 90% of the time and 92% for using the rubber dam $\geq$ 90% of the time.

Final

Isolation Techniques Questionnaire

SECTION 1: PRACTICE CHARACTERISTICS

This section asks if any changes have occurred to your dental practice since you answered the National Dental PBRN Enrollment Questionnaire.

1. When you completed the National Dental PBRN Enrollment Questionnaire you had indicated you were a general dentist. Are you still a general dentist?
   a. Yes [SKIP TO Q3]
   b. No

2. Which **one** of the following best describes your current dental practice?
   a. Endodontist [SKIP TO END OF SURVEY]
   b. Pediatric Dentist [SKIP TO END OF SURVEY]
   c. Periodontist [SKIP TO END OF SURVEY]
   d. Prosthodontist [SKIP TO END OF SURVEY]
   e. Oral/Maxillofacial Surgeon [SKIP TO END OF SURVEY]
   f. Orthodontist [SKIP TO END OF SURVEY]
   g. Other, please specify: _____ [SKIP TO END OF SURVEY]

3. Since you answered the National Dental PBRN Enrollment Questionnaire, have you changed your type of practice (that is: Owner of a private practice; Associate or employee of a private practice; HealthPartners Dental Group; Permanente Dental Associates; Other managed care or preferred provider organization; Public health practice; Federal government facility; Dental school or academic dental institution)?
   a. Yes
   b. No [SKIP TO Q5]

4. Which **one** of the following best characterizes the type of practice in which you currently work?
   a. Owner of a private practice
   b. Associate or employee of a private practice
   c. HealthPartners Dental Group
   d. Permanente Dental Associates
   e. Other managed care or preferred provider organization
   f. Public health practice, community health center, or publicly-funded clinic (but not a federal facility)
   g. Federal government facility (e.g., VA, Department of Defense, Public Health Service)
   h. Dental school, academic dental institution, or facility staffed by the dental school

SECTION 2: GENERAL ROOT CANAL PRACTICES

This section asks questions about your general root canal practices. By "root canals", we mean the number of teeth treated with root canal fillings, rather than the number of canals treated.

5. Do you personally perform **one or more** root canals per month?
   a. Yes
   b. No [SKIP TO END OF SURVEY]

6. Which of the following do you use for endodontic instrumentation? Please select all that apply.
   a. Standard nickel-titanium (NiTi) hand K files
   b. Engine-driven nickel-titanium (NiTi)
   c. Stainless steel hand K files
   d. Rotary endodontic instruments
   e. Some other endodontic instrumentation, please describe:
      _____

7. Which of the following do you use for canal irrigation? Please select all that apply.
   a. Normal saline
   b. Sodium hypochlorite
   c. Local anesthetic solution
   d. Hydrogen peroxide
   e. Chlorhexidine
   f. Some other canal irrigation, please describe: _____

8. Which of the following sealers do you use during root canals? Please select all that apply.
   a. Zinc oxide-eugenol (ZOE)
   b. Epoxy resin based
   c. Calcium hydroxide
   d. Glass ionomer
   e. Some other sealer, please describe: _____

9. Which of the following obturation techniques do you use? Please select all that apply.
   a. Lateral condensation or vertical compaction
   b. Continuous wave technique (vertical compaction of core material and sealer in apical portion of root canal using commercially-available heating devices and then back-filling the remaining portion of the root canal with thermoplasticized core material using injection devices)
   c. Thermoplasticized injection technique (e.g., injection of material at a high temperature))
   d. Carrier-based techniques (gutta percha is coated on a carrier before heating and/or delivery to the canal)
   e. Thermomechanical compaction technique using rotary instruments
   f. Use of paste fillers
   g. Some other obturation technique, please describe: _____

10. Which of the following canal fill materials do you use? Please select all that apply.

a. Gutta percha
b. Resin root filling materials (Resilon®)
c. Resin-coated gutta percha cones
d. Endodontic paste fillers
e. Apical barrier material (e.g., mineral trioxide aggregate)
f. Some other canal fill material, please describe: _____

SECTION 3: ANTERIOR TOOTH ROOT CANAL TREATMENT

This section concerns root canal treatment that you perform on anterior teeth.

11. In an average month, how many anterior tooth root canals do **you** personally perform? If you do not perform anterior tooth root canals, please enter '0'.
    a. [Enter number]

[IF '0', SKIP TO Q13]

12. When **you** personally perform anterior tooth root canals, what percentage of the time do you use the following isolation techniques?
    a. Rubber dam: _____%
    b. Cotton roll or gauze: _____%
    c. Isolite™: _____%
    d. Some other type of isolation technique: _____% Please specify: _____
    e. Some other type of isolation technique: _____% Please specify: _____
    f. No isolation technique is used: _____%

13. In an average month, how many anterior tooth root canals do you **refer** to a different dentist or endodontist? If you do not refer any anterior tooth root canals, please enter '0'.
    a. [Enter number]

SECTION 4: PREMOLAR TOOTH ROOT CANAL TREATMENT

This section concerns root canal treatment that you perform on premolar teeth.

14. In an average month, how many premolar tooth root canals do **you** personally perform? If you do not perform premolar tooth root canals, please enter '0'.
    a. [Enter number]

[IF '0', SKIP TO Q16]

15. When **you** personally perform premolar tooth root canals, what percentage of the time do you use the following isolation techniques?
    a. Rubber dam: _____%
    b. Cotton roll or gauze: _____%
    c. Isolite™: _____%
    d. Some other type of isolation technique: _____% Please specify: _____

e. Some other type of isolation technique: _____% Please specify:
_____

f. No isolation technique is used: _____%

16. In an average month, how many premolar tooth root canals do you **refer** to a different dentist or endodontist? If you do not refer any premolar tooth root canals, please enter '0'.
    a. [Enter number]

SECTION 5: MOLAR TOOTH ROOT CANAL TREATMENT

This section concerns root canal treatment that you perform on molar teeth.

17. In an average month, how many molar tooth root canals do **you** personally perform? If you do not perform molar tooth root canals, please enter '0'.
    a. [Enter number]

[IF '0', SKIP TO Q19]

18. When **you** personally perform molar tooth root canals, what percentage of the time do you use the following isolation techniques?
    a. Rubber dam: _____%
    b. Cotton roll or gauze: _____%
    c. Isolite™: _____%
    d. Some other type of isolation technique: _____% Please specify:
    _____
    e. Some other type of isolation technique: _____% Please specify:
    _____
    f. No isolation technique is used: _____%

19. In an average month, how many molar tooth root canals do you **refer** to a different dentist or endodontist? If you do not refer any molar tooth root canals, please enter '0'.
    a. [Enter number]

SECTION 6: ROOT CANAL TREATMENT ON TEETH WITH GINGIVAL/SUBGINGIVAL CARIES

This section concerns root canal treatment that you perform on teeth with gingival/subgingival caries.

20. In an average month, how many root canals do **you** personally perform on teeth with gingival/subgingival caries? If you do not perform root canals on these teeth, please enter '0'.
    a. [Enter number]

[IF '0' SKIP TO Q22]

21. When **you** personally perform root canals on teeth with gingival/subgingival caries, what percentage of the time do you use the following isolation techniques?
    a. Rubber dam: _____%

b. Cotton roll or gauze: _____%
c. Isolite™: _____%
d. Some other type of isolation technique: _____% Please specify: _____
e. Some other type of isolation technique: _____% Please specify: _____
f. No isolation technique is used: _____%

22. In an average month, how many root canals on teeth with gingival/subgingival caries do you **refer** to a different dentist or endodontist? If you do not refer any of these root canals, please enter '0'.
    a. [Enter number]

SECTION 7: ATTITUDES TOWARD ROOT CANAL PRACTICES AND TREATMENT

Please indicate the extent to which you disagree or agree with the following statements. There are no right or wrong answers to these questions; we are simply interested in your thoughts about the statements below.

23. I received sufficient knowledge and training in dental school on how to effectively place a rubber dam prior to performing a root canal.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

24. Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on **anterior** teeth.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

25. Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on **premolar** teeth.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

26. Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on **molar** teeth.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

27. Isolite™ is just as effective as the rubber dam when root canals are done on **anterior** teeth.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

28. Isolite™ is just as effective as the rubber dam when root canals are done on **premolar** teeth.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Final

29. Isolite™ is just as effective as the rubber dam when root canals are done on **molar** teeth.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

30. Using a rubber dam during root canals reduces the likelihood of infection for patients.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

31. Using a rubber dam during root canals decreases the likelihood of infection for practitioners and office staff.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

32. Using a rubber dam when performing root canals reduces the potential for swallowed or aspirated dental items.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

33. Using rubber dams when performing root canals improves treatment effectiveness.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

34. Rubber dams control moisture very well during root canals.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

35. It's very important to use a rubber dam every time a root canal is performed.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

36. Rubber dams tear frequently.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

37. Rubber dams make it easier to perform root canals.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

38. Most dentists I know use rubber dams when performing root canals.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

39. Placing a rubber dam before performing a root canal is time-consuming.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

40. Clamp placement requires the use of additional anesthesia around the gumline when rubber dams are used to perform root canals.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

41. Using rubber dams to perform root canals is inconvenient.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

42. Patients are uncomfortable wearing a rubber dam during root canals.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

43. Maintaining an adequate supply of rubber dams in one's practice is difficult.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

SECTION 8: SPECIFIC QUESTIONS ABOUT ROOT CANAL PRACTICES

The following questions ask about engaging in a variety of particular tasks or behaviors.
How hard or easy is it for you to .....

44. .....place a rubber dam to perform a root canal?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

45. .....place a rubber dam on an **anterior** tooth to perform a root canal?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

46. .....place a rubber dam on a **premolar** tooth to perform a root canal?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

47. .....place a rubber dam on a **molar** tooth to perform a root canal?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

48. .....fit a clamp that is too big, too small, or of awkward size for the tooth?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

49. .....place a rubber dam when you have limited access and visibility of the isolated operating area?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

50. …..place a rubber dam when the patient doesn't have the ability to open his/her mouth very wide?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

51. …..explain to a patient the importance of using a rubber dam to perform a root canal?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

52. …..communicate with the patient (as needed) during a root canal when a rubber dam is being used?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

53. …..use a rubber dam to perform a root canal with a patient who is claustrophobic, talkative, a gagger, and/or has a breathing problem (e.g., COPD)?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

54. …..get assistance from auxiliary staff to place a rubber dam when needed?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

55. …..use a rubber dam to perform a root canal when you have competing demands in your clinic (e.g., other patients are waiting for you to check them after a cleaning)?

Very Hard	Hard	Neither Hard nor Easy	Easy	Very Easy

SECTION 9: ADDITIONAL COMMENTS

56. Is there anything else you think we should know about how you use isolation methods during root canal treatment?

[OPEN FIELDS FOR TEXT ENTRY BY THE RESPONDENT HERE]

SECTION 10: PAYMENT OPTIONS

57. Would you like us to send you or your practice organization $50.00 as a thank you for completing this survey?

[ ] Yes, please send compensation
[ ] No [SKIP TO END OF SURVEY]

Thank you for completing this questionnaire.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Discordance between presumed standard of care and actual clinical practice: the example of rubber dam use during root canal treatment in the National Dental Practice-Based Research Network

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Discordance between presumed standard of care and actual clinical practice: the example of rubber dam use during root canal treatment in the National Dental Practice-Based Research Network

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ABSTRACT

Objectives: Use of a rubber dam during root canal treatment is considered the standard of care because it enhances patient safety and optimizes the odds of successful treatment. Nonetheless, not all dentists use a rubber dam, creating a disconnect between presumed standard of care and what is actually done in clinical practice. Little is known about dentists' attitudes toward use of the rubber dam in their practices. The objectives were to: (1) quantify these attitudes; and (2) test the hypothesis that specific attitudes are significantly associated with rubber dam use.

Setting: National Dental Practice-Based Research Network (NationalDentalPBRN.org).

Participants: 1,490 network dentists.

Outcome measures: Dentists completed a questionnaire about their attitudes toward rubber dam use during root canal treatment. Three attitude scales comprised 33 items that used a 5-point ordinal scale to measure beliefs about effectiveness, inconvenience, ease of placement, comparison to other isolation techniques, and patient factors. Factor analysis, cluster analysis, and multivariable logistic regression analyzed the relationship between attitudes and rubber dam use.

Results: All items had responses at each point on the 5-point scale, with an overall pattern of substantial variation across dentists. Five attitudinal factors (rubber dam effectiveness; inconvenient/time consuming; ease of placement; effectiveness compared to Isolite; patient factors) and four clusters of practitioners were identified. Each factor and cluster was independently and strongly associated with rubber dam use.

Conclusions: General dentists have substantial variation in attitudes about rubber dam use. Beliefs that rubber dam use is not effective, inconvenient, time consuming, not easy to place, or affected by patient factors, were independently and significantly associated with lower rubber dam use. These

attitudes explain why there is substantial discordance between presumed standard of care and actual practice.

Strengths and limitations of this study

- Large national study of dentists who represent a diverse range of dentist characteristics, practice types, and patient populations served
- Detailed assessment of attitudes about specific clinical treatment that speaks to whether actual clinical practice conforms to a presumed standard of care
- Single point in time based on dentist self-report

BACKGROUND

Routinized attention to patient safety has gradually but systematically permeated health care, from the individual clinician, to health care teams, to health care systems at large.[1-4] This is because patient safety is considered a fundamental aspect of health care and because the role of malpractice claims in health care costs has evolved.[5-8] In addition to causing no harm, the competent clinician is generally regarded as one who provides care consistent with current scientific evidence and the standard of care. Although this summary applies to all fields of medicine, including dental medicine, the dental profession nonetheless provides an example in which clinicians can readily prevent an adverse patient safety event, and optimize the odds of successful treatment, yet choose not to do so.

The example has to do with root canal treatment. Root canal treatment involves: (1) drilling through the biting surface of the tooth; (2) accessing the dental pulp using files to clean and disinfect the root canal system; (3) placing inert filling material in the canals; and (4) placing a material to seal the tooth's crown. To adequately disinfect the root canal system, the dentist must avoid contamination by bacterial sources, such as the patient's own saliva. On rare occasions patients have ingested or aspirated the small instruments required to clean the canals, resulting in injury. If the dentist places a rubber dam around the tooth during endodontic treatment, then the risk of saliva contamination and ingestion of chemicals or aspiration of instruments is reduced.[9,10] Because a rubber dam ensures patient safety and optimizes the odds of treatment success, its use during all root canal treatment is considered the standard of care by a professional consensus of the American Association of Endodontists (root canal specialists)[11] and general dentists. A recent literature review concluded that rubber dam use is also the international standard.[12] Technically, the standard of care in the United States is decided by the legal system on a case-by-case basis.[13-15] However, courts usually rely on a professional consensus about what a reasonable dentist would do in a similar circumstance. Endodontic claims are among the most frequently filed malpractice

claims in dentistry.[16-18] In instances where a patient has ingested or aspirated an instrument, a finding of negligence by the offending dentist would be typical.

Nonetheless, use of a rubber dam during all root canal treatment is not ubiquitous. We previously reported from this study that less than half of United States general dentists always use a rubber dam during root canal treatment.[19] Other United States and non-United States studies also have documented sub-optimal use.[20,21] Some dentists who do not use a rubber dam instead use small cotton rolls to help isolate the tooth even though this may not do an adequate job of preventing saliva contamination and offers no protection against patient injury. Some have advocated the use of other isolation methods, such as an intraoral suctioning and retraction device called Isolite®,[22] although its use can only offer partial protection. Therefore, there is a discordance or "disconnect" in the dental profession between the presumed standard of care and what is done in actual clinical practice.

Unfortunately, little is known about the attitudes that general dentists have about rubber dam use and other isolation methods, and whether these attitudes are related to rubber dam use. Therefore, our objectives were to: (1) quantify these attitudes; and (2) test the hypothesis that these attitudes are significantly associated with whether the dentist uses a rubber dam during root canal treatment, with other dentist and practice characteristics already taken into account.

METHODS

Dentists in the network provide an opportunity to better understand the services that dental practitioners provide. The network is a consortium of dental practices and organizations focused on improving the scientific basis for clinical decision-making.[23] Many details about the network are publicly available.[24]

Enrollment Questionnaire

The applicable network Institutional Review Boards approved the study; participants provided informed

consent after receiving a full explanation of the nature of the procedures. As part of the network enrollment process, practitioners complete an Enrollment Questionnaire that describes characteristics about themselves and their practice(s). Questionnaire items, which had documented test/re-test reliability, were taken from our previous work in a PBRN study of dental care and a network that ultimately led to the National Dental PBRN.[25,26] A copy of the questionnaire is publicly available.[27]

Isolation Techniques questionnaire and its administration

After confirming on the questionnaire that the respondent is a general dentist and does at least one root canal treatment each month, attitudes were measured in: (1) a section that contained 21 "agreement" statements about how strongly one agrees with certain statements, the first 12 of which examined beliefs about the effectiveness of a rubber dam, followed by nine statements about potential problems when using a rubber dam; and (2) 12 "difficulty" statements about how difficult certain root canal treatment practices are. Good test/re-test reliability of these items has been reported previously.[19] A copy of the full questionnaire is publicly available.[28] Qualitative comments were received as a result of including an item at the end of the questionnaire that asked "Is there anything else you think we should know about how you use isolation methods during root canal treatment?", complementing the quantitative findings by providing nuanced information. Comments were received from 678 of the 1491 participants.

We have reported previously details about the survey administration.[19] Briefly, 1,876 dentists who reported on the Enrollment Questionnaire that they were a general dentist; currently practicing/seeing patients; performing at least some root canal treatment; and at least "limited" or "full" network participants were invited to complete the Isolation Techniques questionnaire.

Statistical methods

Analyses were done using SPSS.[29] The main outcomes of interest were the frequency of use of different types of isolation techniques, with attitudes as the key predictors. A principal components analysis with orthogonal rotation was conducted separately for the 21 agreement statements and for the 12 difficulty questions as initial examination and potential factor structure, which supported the existence of multiple attitude dimensions. Items deemed appropriate from each scale were subsequently combined and a final principal components analysis was performed. Principal components were rotated to achieve an orthogonal simple structure and factor regression scores were saved. Factor loadings of .50 and greater were used for interpretation. The Kaiser-Myer-Okin statistic measured sampling adequacy for factor analysis.[30]

Using multivariable logistic regression, factor regression scores were used to examine the relationship between the dentist's attitudes about isolation techniques and whether these techniques were used. In addition, cluster analysis was performed using factor regression scores to identify homogenous subgroups who have similar attitudes about rubber dam as an isolation technique. An advantage of this approach is that decisions are made using a combination of attitudes and beliefs, and cluster membership is determined by each dentist's set of attitudes. Ward's clustering method, with squared Euclidean distances as the similarity measure, was used to be sensitive to differences in elevation as well as profile shape.[31]

RESULTS

Details on eligibility, response rates, differences between participants and non- participants, and characteristics of participants have been previously reported.[19]

Frequency of use of rubber dam and other isolation techniques

Only 47% reported always using a rubber dam during root canal treatment. Cotton rolls are used at

least sometimes by 47% of participants and all the time by 12%. Isolite® was used by 8% (n=126). A total of 3% (n=39) used a method other than rubber dam, cotton roll, or Isolite®. Only 5% (n=70) use no method of isolation. Based on the frequency distributions for each isolation technique, the following cut points were used during subsequent model testing: rubber dam use all the time (n=697, 47% of dentists); and cotton roll use at least 50% of the time (n=283, 19% of dentists). Because of its infrequent use, Isolite® use was not modeled.

Distribution of attitudes items and factor analysis

The wording of the attitude questions is provided in Table 1. The distributions of responses to each item are publicly available.[32] With the exception of question 23 (skew=-1.73, kurtosis=3.0) and question 32 (skew=-2.92, kurtosis=11.43), responses to the agreement statements had skew and kurtosis of less than ± 2; 16 of 21 were ±1. Skew and kurtosis for the difficulty questions were all within ±1 and ranged from -.66 to 0.80 for skew and -.33 to .79 for kurtosis.

The Kaiser-Myer-Okin Measure of Sampling Adequacy was .910 for the agreement statements and .896 for the difficulty questions; these are very high. The 21 agreement statements formed 5 factors with an eigenvalue of greater than 1.0. The final factor consisted of a single item (Q23 – adequate training in dental school) loading higher than .40. The other four factors had at least three items with loadings of .50 or greater. The 12 difficulty questions formed 3 factors, each with four items with loadings of .50 or greater.

Items from both scales were then combined and principal components analysis of the final pool of 31 items was done. Items Q23 and Q32 were not included because of their skewness and kurtosis. The Kaiser-Myer-Okin Measure of Sampling Adequacy was .936. The rotated solution accounted for 62% of the total variance and resulted in a 5-factor solution based on eigenvalues greater than one criterion and scree test. Factors and factor loadings are presented in Table 1. The first factor comprised 10 items from the attitude agreement scale and represented “rubber dam is effective”, accounting for 18% of the variance.

The second factor comprised 10 items predominantly from the agreement attitude scale and represented "using a rubber dam is inconvenient and time consuming", accounting for 13% of the variance. The third factor comprised primary loadings from four items and two secondary loadings of items from the difficulty attitude scale and represented "rubber dam is easy to place", accounting for 12% of the variance. The fourth factor comprised three items from the attitude agreement scale and represented "rubber dam is just as effective as Isolite" and accounted for 10% of the variance. The final factor comprised four items from

Table 1. Factor structure and loadings for attitudes about isolation techniques used during root canal treatment

Question number	Question wording	Factor 1: Rubber dam effectiveness	Factor 2: Inconvenient/ time consuming	Factor 3: Ease of placement	Factor 4: Rubber dam effectiveness compared to Isolite®	Factor 5: Patient factors
	Agreement items					
24	Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on *anterior* teeth.	-.62				
25	Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on *premolar* teeth.	-.70				
26	Cotton rolls or gauze are just as effective as the rubber dam when root canals are done on *molar* teeth.	-.67				
27	Isolite® is just as effective as the rubber dam when root canals are done on *anterior* teeth.				.91	
28	Isolite® is just as effective as the rubber dam when root canals are done on *premolar* teeth.				.94	
29	Isolite® is just as effective as the rubber dam when root canals are done on *molar* teeth.				.88	
30	Using a rubber dam during root canals reduces the likelihood of infection for patients.	.66				
31	Using a rubber dam during root canals decreases the likelihood of infection for practitioners and office staff.	-.69				
33	Using rubber dams when performing root canals improves treatment effectiveness.	.83				
34	Rubber dams control moisture very well during root canals.	.69				
35	It's very important to use a rubber dam every time a root canal is performed.	.77				
36	Rubber dams tear frequently.		.58			
37	Rubber dams make it easier to perform root canals.	.69				
38	Most dentists I know use	.58				

	rubber dams when performing root canals.					
39	Placing a rubber dam before performing a root canal is time-consuming.		.62			
40	Clamp placement requires the use of additional anesthesia around the gum line when rubber dams are used to perform root canals.		.53			
41	Using rubber dams to perform root canals is inconvenient.		.62			
42	Patients are uncomfortable wearing a rubber dam during root canals.		.60			
43	Maintaining an adequate supply of rubber dams in one's practice is difficult.		.45			
	Difficulty items					
	How hard or easy it for you to …					
44	place a rubber dam to perform a root canal?			.74		
45	place a rubber dam on an *anterior* tooth to perform a root canal?			.77		
46	place a rubber dam on a *premolar* tooth to perform a root canal?			.82		
47	place a rubber dam on a *molar* tooth to perform a root canal?			.65		
48	fit a clamp that is too big, too small, or of awkward size for the tooth?					.68
49	place a rubber dam when you have limited access and visibility of the isolated operating area?					.79
50	place a rubber dam when the patient doesn't have the ability to open his/her mouth very wide?					.73
51	explain to a patient the importance of using a rubber dam to perform a root canal?		-.44			
52	communicate with the patient (as needed) during a root canal when a rubber dam is being used?		-.49			
53	use a rubber dam to perform a root canal with a patient who is claustrophobic, talkative, a gagger, and/or has					.59

	a breathing problem (e.g., COPD)?					
54	get assistance from auxiliary staff to place a rubber dam when needed?		-.45	.44		
55	use a rubber dam to perform a root canal when you have competing demands in your clinic (e.g., other patients are waiting for you to check them after a cleaning)?		-.53	.46		

the difficulty scale and represented "patient factors do not complicate the use of a rubber dam", accounting for 9% of the variance.

Logistic Regression

With the outcome as using a rubber dam all of the time, dentists who more strongly agreed that a rubber dam is effective ($p < .001$), who rated a rubber dam as easy to place ($p < .001$), and who believe that patient factors do not complicate rubber dam use ($p < .001$,) were more likely to use a rubber dam all of the time (Table 2). Dentists who agreed more strongly that using a rubber dam is inconvenient and time consuming ($p < .001$) or that using rubber dam is just as effective as Isolite®, were less likely to use a rubber dam all of the time (Table 2).

Table 2. Multivariable logistic regression quantifying the relationship between dentists' attitudes and rubber dam use

	Parameter estimate (Standard Error)	p-value	Odds Ratio (95% Confidence Interval of the Odds Ratio)
Attitudes			
Rubber dam effectiveness	1.43 (.11)	< .001	4.17 (3.35 - 5.18)
Inconvenient/time consuming	-0.78 (.08)	< .001	0.46 (0.39 - 0.54)
Ease of placement	0.50 (.08)	< .001	1.65 (1.42 - 1.93)
Rubber dam effectiveness compared to Isolite®	-1.17 (.09)	< .001	0.31 (0.26 - 0.36)
Patient factors	0.43 (.08)	< .001	1.52 (1.31 - 1.76)
Dentist and practice characteristics			
Endodontist in same building	0.46 (.46)	0.32	1.58 (0.65 – 3.87)
Public health practice model (reference is large group practice)	-1.21 (.43)	0.01	0.30 (0.13 - 0.69)
Private practice model (reference is large group practice)	-1.07 (.28)	<.001	0.34 (0.20 - 0.59)
Dentist gender (male)	-0.21 (.18)	0.26	0.81 (0.57 - 1.17)
Decades since dental school graduation	-0.17 (.07)	0.02	0.85 (0.74 - 0.97)
Any additional training since dental school	0.26 (.15)	0.08	1.30 (0.97 - 1.73)
Rural work setting	-0.44 (.20)	0.03	0.64 (0.44 - 0.95)
Does fewer than 10 root canals each month	-0.37 (.16)	0.02	0.69 (0.51 - 0.94)

The outcome of interest is whether or not the dentist uses a rubber dam all of the time during root canal treatment.

The regression is adjusted for differences in dentist gender (female=0, male=1); decades since dental school graduation truncated at 30+ coded (0-9=1, 10-19=2, 20-29=3, 30+=4); additional training since dental school (no training=0, additional=1); practice type (large group practice=0, private practice=1, public health/government/other=1); whether the practice is located in a rural setting (urban/suburban=0, rural=1); whether an endodontist is located in the same building as the practice (no=0, yes=1); and whether the dentist does fewer than 10 RCT each month (10 or more=0, less than 10=1).

The model fit was statistically significant (n= 1445, chi-square = 802.7, $p < .001$ with df=13). Nagelkerke's R^2 of .57. The prediction success overall was 80% (80% for using a rubber dam all the time and 80% for not using the rubber dam all the time).

Cluster Analysis

Examination of differences in potential clusters and inspection of mean factor scores for each cluster, suggested that a four-cluster solution is the most appropriate and interpretable.[32,33] Mean factor regression scores and frequencies for choice of isolation techniques for each cluster are presented in Tables 3 and 4,

respectively.

Table 3. Factor regression scores for each of the five attitude factors, by cluster.

	Rubber dam effective-ness	Ease of placement	Inconvenient/ time consuming	Compared to Isolite®	Patient factors
Cluster 1: Rubber dam not effective and not easy to place (n=252)	-1.50	-.44	.18	.25	-.35
Cluster 2: Rubber dam moderately effective but inconvenient/time consuming (n=302)	-.08	.14	.75	.63	-.14
Cluster 3: Rubber dam is effective but inconvenient/time consuming and not easy to place (n=504)	.42	-.31	-.45	.45	.25
Cluster 4: Rubber dam is effective and much more so than Isolite® (n=401)	.40	.19	-.10	-1.20	.09

n=1,459. Factor regression scores are standardized scores with an overall sample mean=0 and SD=1. Mean factor regression scores for each cluster represent the difference between each cluster's mean and the overall mean of the sample. For example, the -1.50 score for cluster 1 on "Rubber dam effectiveness" is interpreted as 1.5 standard deviations less than the overall mean for that factor. The advantage over scale scores is that factor regression scores can be compared to each other directly.

Table 4. Frequency of use of isolation techniques, by cluster.

	% who use RD all of the time	% who use cotton rolls at least 50% of the time	% use Isolite®
Cluster 1: Rubber dam not effective and not easy to place (n=252)	7	61	11
Cluster 2: Rubber dam moderately effective but inconvenient/time consuming (n=302)	39	24	11
Cluster 3: Rubber dam is effective but inconvenient/time consuming and not easy to place (n=504)	44	8	11
Cluster 4: Rubber dam is effective and much more so than Isolite® (n=401)	82	3	1

The first cluster comprised 252 dentists who held attitudes that rubber dam use is not effective and not easy to place. They also held the attitude that perceived patient factors "do complicate" the use of a rubber dam. This group was least likely to use a rubber dam all the time (7% use a rubber dam all of the time) and the most likely to use a cotton roll at least half the time (61% of the cluster). The second cluster comprised 302 dentists who had the highest agreement on statements that rubber dam use is inconvenient and time consuming. They were near the overall mean for whether rubber dam is effective and easy to place. They also held the belief that Isolite® is just as effective as rubber dam. As a group, they were second least likely to use a rubber dam (39% use a rubber dam all of the time). The third cluster comprised 504 dentists. This group was most likely to agree with statements that rubber dam use was inconvenient and time consuming and held the attitude that rubber dam use is effective. Nevertheless, they did believe that rubber dam can be difficult to place, but that patient factors were not the issue. This group used the rubber dam at similar frequencies to the second group (44% use a rubber dam all of the time) and were not frequent users of a cotton roll. The fourth cluster comprised 401 general dentists, who held the attitude that rubber dam use is effective and were close to the overall mean on whether rubber dam use was inconvenient and time consuming. This was the group who most strongly disagreed with statements that Isolite® is just as effective as rubber dam. As a group, they almost exclusively used a rubber dam for root canal treatment (82% use a rubber dam all of the time) and almost never used Isolite®.

DISCUSSION

Although almost all (96%) agreed that using a rubber dam reduces the potential for ingestion or aspiration, only 78% agreed that rubber dam use improves treatment effectiveness. This latter percentage is consistent with the minority (from 6%-24%, depending on the question, for questions 24-29) who agreed that cotton roll or Isolite® use is just as effective as a rubber dam. In one of the few studies ever to evaluate dentist attitudes toward rubber dam use, a study of 300 dentists in Ireland found that only 42% agreed with

the statement "Root canal fillings placed without rubber dam isolation are as successful as when rubber dam isolation is used".[34] A study of final-year dental students at two British dental schools observed that 10% agreed with "Root canal fillings placed without rubber dam are as successful as those isolated with rubber dam" and 68% agreed with "Rubber enables a higher clinical standard to be achieved".[35] Unfortunately, neither of these two studies related the attitudes to whether or not the dentist reported actually using a rubber dam or intended to. A 2009 review of the literature concluded that lack of patient acceptance and the time required to apply the rubber dam were the most common reasons.[21] The same review also concluded that patient acceptance is actually very high and can be influenced substantially by the enthusiasm and experience of the dentist and dental assistant.[21] We are aware of no United States dental school that does not require use of a rubber dam during root canal treatment, regardless of whether the treatment is being done by a student, resident, or faculty member. Our sense is that schools consider a tooth inappropriate for root canal treatment if a rubber dam cannot be placed; in those cases, root canal treatment is not done and the tooth is recommended for extraction.

We conclude from the results in Tables 2-4 that several key factors are associated with rubber dam use. Attitudes about rubber dam use for treatment effectiveness and patient safety, either alone or in comparison to Isolite®, seem to be the main factors, with additional contributions from inconvenience, ease of use, and patient factors. These results make it clear that there is not a profession-wide consensus about the importance of rubber dam use. Regarding the patient safety issue, the profession may benefit from an effort similar to what has occurred in surgery regarding "never events",[4] which like patient ingestion or aspiration of root canal treatment instruments are rare, but nonetheless are so egregious that they warrant a routinized approach to their avoidance. Regarding treatment effectiveness, the evidence that rubber dam use improves long-term treatment effectiveness is limited,[36,37] but is it clear that to adequately disinfect the root canal system, the dentist must avoid contamination by bacterial sources, such as from the patient's own saliva. Note that the results in Table 2 are also adjusted for key dentist and practice characteristics,

and that most of these were also significantly associated with rubber dam use. All of these variables are modeled as main independent effects. However, it is possible that the correlation between certain main effects could also affect the results, such as a direct effect due to additional training or experience, which then could affect the dentist's attitudes toward rubber dam use.

Although 47% of network dentists reported using a rubber dam all of the time, 16% reported using it from 90%-99% of the time. It is possible that this latter group of dentists begins with an intention to use the rubber dam for a given patient, but decides not to if they have trouble placing it or if the patient expresses a strong desire not to have a rubber dam placed. This would be consistent with the approximate percentage of dentists who agreed or strongly agreed with the difficulties queried in the Factor 5 (patient factors) items. For this reason, we repeated the multivariable logistic regression in Table 2, except that the outcome of interest was rubber dam use of 90% or more, instead of all the time (results not shown, but publicly available as Table A2 [32]). However, the substantive conclusions were the same.

This study does have certain limitations, and conclusions made from it should take these into account.[19] Although network practitioners have much in common with dentists at large,[38,39] it is possible that their root canal treatment procedures are not representative of dentists at large. Additionally, network members are not recruited randomly, so factors associated with network participation (e.g., an interest in clinical research) may make network dentists unrepresentative of dentists at large. While we cannot assert that network dentists are entirely representative, we can state that they have much in common with dentists at large, while also offering substantial diversity in these characteristics.[19]

Results from this study can inform a next-stage intervention targeted to network members and potentially to the dental profession at large. Dissemination and scale-up approaches could be used which are targeted to practitioners who report no or low rubber dam use.[40] These approaches have been used successfully in the network regarding treatment of early dental decay.[41-43] The often-lamented "research-to-practice gap" refers to the delay between what research evidence suggests should be happening in

routine clinical practice, and what is actually happening. The results in this study suggest that the gap relevant to rubber dam use is a circumstance in which knowledge is available and providers are aware of it, but they have not yet implemented the recommended changes. Qualitative comments provided at the end of the questionnaire complemented the quantitative findings by providing nuanced information. For example, practitioners are generally well aware of the potential for adverse patient safety events, the potential for reduction in treatment effectiveness, and the presumed standard of care. However, their retort is oftentimes their own individual clinical experience that they have not had these problems, in concert with their experience that rubber dam can be difficult to place or not wanted by patients. Other practitioners who routinely use a rubber dam suggested that rubber dam placement is simple and that reports by other practitioners can be ascribed to insufficient training during dental school or not having dental assistants available during dental school or residency, leading them to an early but unwarranted conclusion that rubber dam use is not acceptable to patients, too difficult, or not necessary.

List of abbreviations

PBRN: practice-based research network

RD: rubber dam

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about the nation's network is located at http://NationalDentalPBRN.org. Persons who comprise the National Dental PBRN Collaborative Group are listed at http://nationaldentalpbrn.org/collaborative-group.php.

Author contributors

GHG, PDE, and PLR contributed to study design and questionnaire testing. JLR and GHG conducted the analysis and review of the data and drafted the initial version of the manuscript. All authors were involved in the intellectual content and drafting of the manuscript, read and approved the final manuscript, and agree to be accountable for all aspects of the work.

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Competing interests

No, there are no competing interests.

Ethic approval

Obtained.

Provenance and peer review

Not commissioned; externally peer-reviewed.

Data sharing statement

No additional data are available.

REFERENCES

1. Bishop A, Fleming M. Patient safety and engagement at the frontlines of healthcare. *Healthc Q* 2014;17 Spec No:36-40.
2. Berkowitz RL. Of parachutes and patient care: a call to action. *Am J Obstet Gynecol* 2011;205(1):7-9.
3. Galbraith RM, Holtman MC, Clyman SG. Use of assessment to reinforce patient safety as a habit. *Qual Saf Health Care* 2006;15(Suppl 1):i30-i33.
4. Mehtsun WT, Ibrahim AM, Diener-West M, Pronovost PJ, Makary MA. Surgical never events in the United States. *Surgery* 2013;153(4):465-472.
5. Mello MM, Studdert DM, Kachalia A. The medical liability climate and prospects for reform. *JAMA* 2014;312(20):2146-2155.
6. Wallace E, Lowry J, Smith SM, Fahey T. The epidemiology of malpractice claims in primary care: a systematic review. *BMJ Open* 2013;3(7):e002929.
7. Oyebode F. Clinical errors and medical negligence. *Med Princ Pract* 2013;22(4):323-333.
8. Institute of Medicine (US) Committee on Quality of Health Care in America; Kohn LT, Corrigan JM, Donaldson MS, editors. To Err is Human: Building a Safer Health System. Washington (DC): National Academies Press (US); 2000.
9. Tooth Morphology, Isolation, and Access Prep. In: Hargreaves KM, Berman LH, eds. Cohen's Pathways of the Pulp. 11th edition, St.Louis, MO: Elsevier, 2015.
10. Fors UG, Berg JO, Sandberg H. Microbiological investigation of saliva leakage between the rubber dam and tooth during endodontic treatment. *J Endod* 1986;12(9):396-399.
11. American Association of Endodontists. AAE Position Statement: Dental Dams. Available at http://www.aae.org/uploadedfiles/clinical_resources/guidelines_and_position_statements/dentaldamstatement.pdf. Accessed October 16, 2015.

12. Ahmed HMA, Cohen S, Levy G, Steier L, Bukiet F. Rubber dam application in endodontic practice: an update on critical educational and ethical dilemmas. *Austr Dent J* 2014; 59(4):457-463.
13. McMurtrie L. Setting the legal standard of care for treatment and evidence-based medicine: a case study of antenatal corticosteroids. *J Law Med* 2006;14(2):220-227.
14. Kozlick D. Clinical practice guidelines and the legal standard of care: warnings, predictions, and interdisciplinary encounters. *Health Law J* 2011;19:125-151.
15. Brenner LH, Brenner AT, Awerbuch EJ, Horwitz D. Beyond the standard of care: a new model to judge medical negligence. *Clin Orthop Relat Res* 2012;470(5):1357-1364.
16. Givol N, Rosen E, Taicher S, Tsesis I. Risk management in endodontics. *J Endod* 2010;36(6):982-984.
17. Perea-Pérez B, Labajo-González E, Santiago-Sáez A, Albarrán-Juan E, Villa-Vigil A. Analysis of 415 adverse events in dental practice in Spain from 2000 to 2010. *Med Oral Patol Oral Cir Bucal* 2014;19(5):e500-e505.
18. Webber J. Risk management in clinical practice. Part 4. Endodontics. *Br Dent J* 2010;209(4):161-170.
19. Lawson NC, Gilbert GH, Funkhouser E, Eleazer PD, Benjamin PL, Worley DC, National Dental PBRN Collaborative Group. General dentists' use of isolation techniques during endodontic procedures: from the National Dental Practice-Based Research Network. *J Endod* 2015;41(8):1219-1225.
20. Savani GM, Sabbah W, Sedgley CM, Whitten B. Current trends in endodontic treatment by general dental practitioners: report of a United States national survey. *J Endod* 2014;40(5):618-624.
21. Ahmad IA. A Rubber dam usage for endodontic treatment: a review. *Int Endod J* 2009;42(11):963–972.
22. Wahl P, Andrews T, Isolation: a look at the differences and benefits of rubber dam and Isolite. *Endo Practice* 2010;(3)2:52-55.

23. Gilbert GH, Williams OD, Korelitz JJ, Fellows JL, Gordan VV, Makhija SK, Meyerowitz C, Oates TW, Rindal DB, Benjamin PL, Foy PJ for the National Dental PBRN Collaborative Group. Purpose, structure and function of the United States National Dental Practice-Based Research Network. *J Dent* 2013;41(11):1051-1059.

24. The National Dental Practice-Based Research Network, the nation's network. Available at: "http://nationaldentalpbrn.org/". Accessed October 15, 2015.

25. The Florida Dental Care Study. Available at: "http://nersp.nerdc.ufl.edu/~gilbert/". Accessed October 15, 2015.

26. Gilbert GH, Richman JS, Gordan VV, Rindal DB, Fellows JL, Benjamin PL, Wallace-Dawson M, Williams OD, DPBRN Collaborative Group. Lessons learned during the conduct of clinical studies in the Dental PBRN. *J Dent Educ* 2011;75(4):453-465.

27. Enrollment Page, National Dental PBRN. Available at: http://nationaldentalpbrn.org/enrollment.php. Accessed October 15, 2015.

28. Study Results Page, National Dental PBRN, Isolation Techniques Used When Performing Root Canal Treatment section. Available at http://nationaldentalpbrn.org/study-results.php. Accessed October 15, 2015. The questionnaire is directly accessible at http://nationaldentalpbrn.org/tyfoon/site/fckeditor/file/IsolationTechniquesQuestionnaire-2013-12-27-V10%200(Clean)_Annotation.pdf.

29. IBM SPSS Statistics 22 Documentation. IBM Software Group, Chicago, IL. Available at: http://www-01.ibm.com/support/docview.wss?uid=swg27038407. Accessed October 15, 2015.

30. Cerny, CA, Kaiser, HF. A study of a measure of sampling adequacy for factor-analytic correlation matrices. *Multiv Behav Res* 1977;12(1):43-47.

31. Overall JE, Gibson JM, Novy DM. Population recovery capabilities of 35 cluster analysis methods. *J Clin Psychol* 1993;49:459-470.

32. Study Results Page, National Dental PBRN. Available at http://nationaldentalpbrn.org/study-results.php. Accessed October 15, 2015.

33. Milligan GA, Cooper MC. An examination of procedures for determining the number of clusters in a data set. *Psychometrika* 1967;50:159-179.

34. Lynch CD, McConnell RJ Attitudes and use of rubber dam by Irish general dental practitioners. *Int Endod J* 2007;40(6):427-432.

35. Mala S, Lynch CD, Burke FM, Dummer PMH. Attitudes of final year dental students to the use of rubber dam. *Int Endo J* 2009;42(7):632-638.

36. Lin PY, Huang SH, Chang HJ, Chi LY. The effect of rubber dam usage on the survival rate of teeth receiving initial root canal treatment: a nationwide population-based study. *J Endod* 2014;40(11):1733-1737.

37. Goldfein J, Speirs C, Finkelman M, Amato R. Rubber dam use during post placement influences the success of root canal-treated teeth. *J Endod* 2013;39(12):1481-1484.

38. Makhija SK, Gilbert GH, DB Rindal, PL Benjamin, JS Richman, DJ Pihlstrom, V Qvist, DPBRN Collaborative Group. Dentists in practice-based research networks have much in common with dentists at large: evidence from the Dental PBRN. *Gen Dent* 2009;57(3):270-275.

39. Makhija SK, Gilbert GH, Rindal DB, Benjamin PL, Richman JS, Pihlstrom DJ, Qvist V, DPBRN Collaborative Group. Practices participating in a dental PBRN have substantial and advantageous diversity even though as a group they have much in common with dentists at large. *BMC Oral Health* 2009;9(1):26-35.

40. Brownson RC, Colditz GA, Proctor EK. Dissemination and implementation research in health: translating science to practice. New York: Oxford University Press, Inc.; 2012.

41. Gilbert GH, Richman JS, Qvist V, Pihlstrom DJ, Foy PJ, Gordan VV. Change in stated clinical practice associated with participation in the Dental Practice-Based Research Network. *Gen Dent* 2010;58:520-528.

42. Gilbert GH, Gordan VV, Funkhouser EM, Rindal DB, Fellows JL, Qvist V, Anderson G, Worley D. Caries treatment in a dental practice-based research network: movement toward stated evidence-based treatment. *Community Dent Oral Epidemiol* 2012;41:143-153.

43. Rindal DB, Flottemesch TJ, Durand EU, Godlevsky OV, Schmidt A, Gesko DS, Gilbert GH, National Dental PBRN Collaborative Group. Practice change toward better adherence to evidence-based treatment of early dental decay in the National Dental PBRN. *Impl Sci* 2014;9:177.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.