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The effect of rubber dam on atmospheric bacterial aerosols during restorative dentistry

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Summary Rotatory dental instruments generate atmospheric aerosols that settle on various surfaces, including the dentist's head. The aim of this study was to quantitatively assess bacterial contamination of the dentist's head and to evaluate whether it is affected by using a rubber dam. Senior dental students ($n = 52$) were asked to wear autoclaved headscarves as collection media while performing restorative dental treatment with and without a rubber dam. Four points from each headscarf were swabbed for bacterial culture after 30 min of operative work. Bacterial contamination was quantified by counting the colony-forming units. Regardless of the collection point, using a rubber dam was associated with more bacterial colony-forming units than not using a rubber dam ($P = 0.009$). Despite its clinical value, the rubber dam seems to result in significantly higher aerosol levels on various areas of the dentist's head, requiring that dentists cover their heads with suitable protective wear.

Introduction

Dentistry is a clinical profession that is associated with biological, chemical and physical hazards. The surgical nature of clinical dental practice, and the dentist's position in close proximity to the patient, put the dentist at risk of microbial infections, which can be transmitted by direct contact or by atmospheric aerosols.

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Several studies have demonstrated microbiological contamination of various clinical surfaces in hospitals and dental clinics [1—5]. Clinician's attire, such as scrubs and white coats, were found to harbor a plethora of bacterial species at high quantities [6—8]. Pathogenicity of microorganisms detected on clinical surfaces ranged in their severity; with some being the cause of serious illnesses, such as measles and tuberculosis [9].

To minimize exposure to potentially pathological microorganisms, the Center for Disease Control and Prevention (CDC) recommends that all dental healthcare providers (DHCPs) use barriers to cover clinical surfaces as well as personal protective equipment (PPE) (gloves, masks, goggles and gowns) to cover their skin and mucous membranes of eyes, nose and mouth when performing dental treatments. The CDC also recommends the use of high velocity suction and rubber dams to reduce the aerosols generated during rotatory dental procedures [10].

The rubber dam is a disposable rubber sheet that is stretched around the treated tooth/teeth, isolating the treatment zone from saliva. The use of a rubber dam during restorative and endodontic treatments is considered the standard of care in most dental care-providing clinics and hospitals. Its use has been associated with higher rates of dental treatment success [11]. Additionally, Cochran et al. and Samaranayake et al., in two separate studies, observed a significant reduction in bacterial atmospheric contamination when rubber dams were used [12,13].

Nevertheless, the amount of bacteria-contaminated spatter accumulating onto the clinician's head, with and without the use of a rubber dam, has not been previously investigated. The objective of this study was to determine the effect of using a rubber dam on the amount of bacteria cultured from various regions of the clinician's head during routine restorative dental treatment.

Materials and methods

Sample and setting

Female dental students in their fourth and fifth years, who would customarily wear headscarves, were invited to participate in this study. The study took place at the University Dental Hospital Sharjah (UDHS) in the United Arab Emirates during the 2013/2014 academic year. UDHS is a 114-dental chair ambulatory hospital that is owned and administered by the College of Dental Medicine at the University of Sharjah. The hospital was inaugurated in 2011 to provide advanced dental clinical training at the graduate and post-graduate levels.

Students who consented to participate ($n = 52$) were randomly assigned into two equal groups using computer-generated random numbers and then assigned to a dental clinic where they performed a routine restorative dental procedure. To standardize the extent of the dental procedure, only dental cavity preparations on posterior teeth that were already planned for the patients were included. A colleague from the same group was assigned to assist each student by holding the surgical suction tube throughout the clinical procedure. All students wore similar PPE, consisting of a disposable apron, mask, gloves and plastic goggles. Half the sample ($n = 26$) was asked to perform this procedure while a rubber dam was placed over the tooth that was being treated, while the other half ($n = 26$) performed similar procedures without a rubber dam. This study was approved by the UDHS Executive Director and was exempted from full review by the Research Ethics Committee as it was a clinical audit.

Microbiological assessment

Fifty-two unused cotton-polyester scarves were packed in plastic pouches and sterilized by autoclave with the temperature set at 132 °C for 30 min. In this way, the colony forming unit (CFU) baseline was set to zero. Each scarf was removed from its pouch using clean gloves and the participants donned the scarves immediately before starting the procedures. Students were instructed to wrap the scarves around their head and neck in the same manner as they would normally do with their customary headscarves. They were asked to avoid touching the scarf throughout the duration of the 30-min procedure. Participants were then asked to begin cavity preparation; 30 min into the operative work, participants were asked to pause their work to allow for bacterial swabbing.

Sterile cotton swabs that were moistened with sterile normal saline were used to sample each headscarf. The sterile cotton swabs were passed twice (up and down) over an area measuring approximately 3 cm × 3 cm. Four sampling areas on each headscarf were pre-determined, and the swabbing process was calibrated using a visual guide (Fig. 1). The four sampling areas were as follows: the area overlaying the forehead (designated as point A), the area overlaying the left ear (point B), the area overlaying the submental triangle (point C), and the area overlaying the occiput

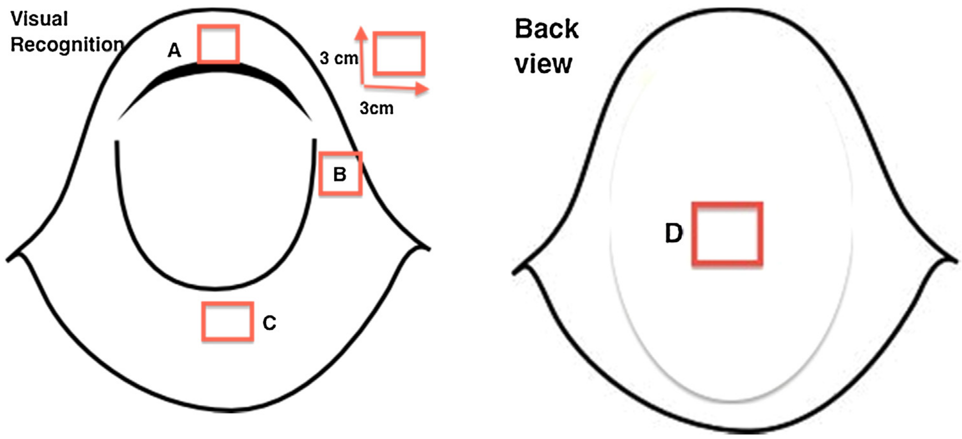

Figure 1 Visual guide used by researchers to collect samples from the scarves using swabs.

(point D). The swabs were placed in their labeled tubes and transported to the Microbiology Department of the College of Health Sciences, University of Sharjah for culturing. Each swab was immediately streaked onto a marked Petri dish containing Tryptikase Soy Agar. The plates were then aerobically incubated at 37 °C for 24 h and the CFUs on each plate were counted and recorded.

Statistical analysis

Data processing and analyses were performed using IBM SPSS/PASW, version 22 (IBM Corp). Comparison between the mean CFU of the four points was performed using analysis of variance (ANOVA). The relationship between rubber dam use, as the independent variable, and the overall CFU for each of the four points was determined using independent *t*-test. Two-way ANOVA was used to assess the relationship between rubber dam use, the location of each point and the CFU. The level of significance was set at alpha = 0.05.

Results

Fifty-two female students enrolled in this study. During the course of cavity preparation, 2 participants were excluded due to changes in the dental procedure type intra-operatively (from restorative cavity preparation to access opening and inlay preparation) and 3 students had to use a face shield and were dropped out. The final sample consisted of 47 students with 188 collection points (four points for each student). Of those collection points, 16 were outliers in that they were more than three standard deviations above the mean. These 16 outliers were excluded from statistical analysis. The majority of the outliers (13 collection points) belonged to the rubber dam group. The final sample size was 47 (22 in the rubber dam group and 25 in the non-rubber dam group). The final number of collection points was 172.

Four students (8.5%) had zero CFU values in all collection points. Three of these belonged to the non-rubber dam group. On average, the points in the rubber dam group had more CFUs than the non-rubber dam group, but this difference was not statistically significant (Fig. 2). Table 1 shows the results of one-way analysis of variance; point A (forehead) had significantly more CFUs (mean: 2.19, SD: 3.04) than the three other points ($P = 0.036$). However, two-way analysis of variance showed that using a rubber dam was associated with significantly higher CFUs ($P = 0.009$) (Table 2). In this study, the interaction between rubber dam use and the location of the points was not statistically significant ($P = 0.95$).

Discussion

Several studies have demonstrated a wide spreading of bacteria onto various surfaces in the dental clinic as a result of aerosols generated from dental rotatory instruments [1,4,14,15]. The bacterial contamination was beyond expectations in terms of the total area of contamination and the quantity and pathogenicity of the bacteria. For example, Rautemaa et al. cultured bacteria at areas well beyond the site of aerosol generation (the dental chair) [4], and Decraene et al. found that nearly half of the bacterial species isolated in the atmosphere of a dental clinic were resistant to at least one commonly used antibiotic [5]. These findings demonstrate that pathological bacteria can be

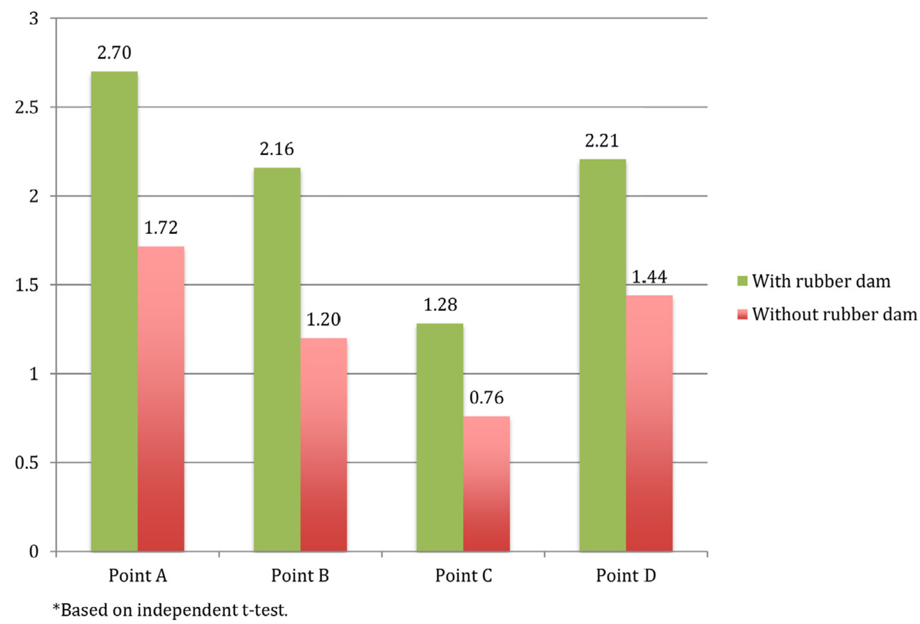

Figure 2 Descriptive analysis between the four points, with and without using a rubber dam*. There is no difference between individual points whether rubber dam is used or not. *P*-values are 0.263 (point A); 0.071 (point B); 0.110 (point C); 0.223 (point D).

Table 1 Relationship between CFU and the points adjusted for rubber dam use.

Variables	TYPE III sum of squares	df	Mean square	*F*	*P*-value
Points[a]	35.129	3	11.710	2.598	0.054
Rubber dam use[b]	31.295	1	31.295	6.944	0.009
Point*Rubber dam use	1.656	3	.552	.122	0.947

Regardless of the area on the head, CFU was higher when using a rubber dam by comparison to not using a rubber dam.
[a] Points are: A (above the forehead), B (over the right ear), C (above the submental triangle), D (the occiput).
[b] Rubber dam used or not used during operative work.

transmitted from the patient's oral cavity to various surfaces within the dental clinic.

Nejatidanesh et al. indirectly investigated the pattern of splatter onto the dentist's face using a face shield as the study medium [16]. The aerosols that affect the dentist's head have not been previously investigated, which is probably because of the inability to perform reproducible swabbing of the head, including the hair, as well as to singly colonize the bacteria generated from dental operative work.

Table 2 Assessment of means CFU by points.[a]

	Total Mean (SD)
Point A	2.19 (3.04)[a]
Point B	1.66 (1.82)
Point C	1.01 (1.09)
Point D	1.81 (2.15)

[a] Based on ANOVA.
Point A is significantly different than point C. *P*-value = 0.036.

In our study, we overcame this obstacle by using an autoclavable surface (a headscarf) from which the bacteria-contaminated aerosols were swabbed and cultured. This approach allowed us to set the baseline bacterial contamination to zero. Moreover, our sample consisted of female students who normally use headscarves as part of their Islamic dress code. As a result, the students were not hindered by the use of this collection surface (a headscarf) during routine operative dental work.

The use of a rubber dam in clinical practice significantly affects the quality of dental restorations by isolating the dental cavity from saliva and blood, which often results in restoration failure [11,17]. In this clinical audit, we wanted to evaluate whether the use of a rubber dam, with its known advantages, impacts the level of aerosols settling on the clinician's head during a 30-min restorative dental treatment.

For each of the collection points, the average number of colony-forming units (CFU) was higher in the rubber dam group than in the non-rubber dam group (Fig. 2). The difference between the two groups for each point was not statistically significant. However, when an adjustment was made for all collection points, the presence of a rubber dam was associated with significantly more bacteria-containing aerosols based on the CFU counts ($P = 0.009$) (Table 2). Those results indicate that the use of a rubber dam is associated with significantly higher bacterial aerosol levels in spite of its clinical benefits.

Our sample consisted of dental students who have limited clinical experience. This can be considered a limitation to the generalizability of the study findings. Additionally, because the dental procedures were pre-planned according to each patient's treatment needs, some variables could not be controlled. These include the location of the treated tooth (maxillary or mandibular). Nevertheless, the selection of a homogeneous group of participants who have similar clinical experience (4th and 5th year dental students), the procedure they performed (cavity preparation of a posterior tooth) and the procedure duration (30 min) reduce the heterogeneity and augment standardization. Despite instructing participating students to avoid touching the headscarves during the 30-min procedure, artifactual contamination cannot be entirely discounted. Accordingly, the values that were calculated as outliers were considered factitious and were eliminated from all statistical analyses.

Interestingly, we found that it is possible to complete a 30-min dental operative procedure without aerosols landing on the head, particularly when a rubber dam is not used. As the study evaluated students during their clinical training years, it cannot necessarily be generalized to more experienced dentists. Further research is needed to determine if clinical experience affects the aerosol levels that are generated during dental procedures.

Current infection control protocols, which include the use of gloves, masks and goggles, are insufficient to prevent bacterial contamination to the head. Those protocols should be extended to include a disposable head cap whenever rotatory dental instruments are used, especially when a rubber dam is applied.

This study quantitatively measured the bacterial aerosols on the head. Future studies are needed to identify the microbiological species as well as their pathogenicity and resistance to antibiotics to precisely determine the health hazards of dental aerosols.

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Competing interests

The authors declare that they have no conflicts of interest for any part of this research.

Ethical approval

Not required.

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Rubber dam application in endodontic practice: an update on critical educational and ethical dilemmas

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ABSTRACT

Proper isolation is an essential prerequisite for successful endodontic treatment. This article aims to provide an update on the prevalence of rubber dam (RD) use, and the role of education along with attitudes of general dental practitioners (GDPs) and patients towards the application of RD in endodontics. Critical ethical issues are also highlighted. Using certain keywords, an electronic search was conducted spanning the period from January 1983 to April 2013 to identify the available related investigations, and the pooled data were then analysed. The results show that although RD is the Standard of Care in endodontic practice, there is a clear discrepancy in what GDPs are taught in dental school and what they practice after graduation. There is little scientific evidence to support the application of RD; however, patient safety and clinical practice guidelines indicate that it is unnecessary and unethical to consider a cohort study to prove what is already universally agreed upon. A few clinical situations may require special management which should be highlighted in the current guidelines. This would pave the way for clear and straightforward universal guidelines.

Keywords: Attitude, dental practitioners, education, endodontics, ethics, rubber dam.

Abbreviations and acronyms: GDPs = general dental practitioners; RD = rubber dam.

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INTRODUCTION

'Endodontic procedures must never be performed without the rubber dam' is the title of a paper by Heling and Heling[1] that clearly emphasizes the essential role of the rubber dam (RD) for every endodontic procedure. For more than 150 years, it has been known that RD use reduces microbial contamination and the potential for patients swallowing or inhaling irrigants, hand-files, infected tooth debris, etc. Furthermore, every dental student is taught early in instruction that in clinical practice the RD enhances visibility, improves visual access to the canal(s), optimizes moisture control and retraction of the soft tissue, thus enhancing the efficiency of every endodontic treatment procedure.[2–5]

Therefore, it is clear that the RD represents the indispensable Gold Standard of Care in endodontic practice.[6] Despite this, a recent clinical survey by Anabtawi *et al.*[5] has shown that only 44% of general dental practitioners (GDPs) use RD for every tooth scheduled for endodontic treatment. This surprising finding indicates a clear discrepancy between the expected learning outcomes in higher dental education and attitude of GDPs before and after graduation. This article aims to discuss the prevalence of RD use amongst different countries. The role of education and attitude of GDPs and patients towards the application of RD is also analysed. Finally, critical ethical issues and considerations are discussed.

LITERATURE SEARCH METHODOLOGY

A PubMed electronic search was conducted spanning the period from January 1983 to April 2013 to identify the available investigations written in the English language and published on the application of the RD in endodontic practice using the following keywords: 'rubber dam' AND 'endodontic treatment' OR 'endodontic therapy' OR 'root canal therapy' OR 'root canal treatment' AND 'prevalence' OR 'education' OR 'attitude' OR 'ethics'. After deleting duplicated papers, the selected data were analysed and divided into two main categories: prevalence of RD use and attitude towards RD use. Ethical issues and considerations are also discussed based on the pooled data and current guidelines in endodontic practice.

Prevalence of rubber dam use

The results shown in Table 1 indicate that, in contrast to undergraduate students, the prevalence of RD use by GDPs amongst different countries in all/most of their endodontic cases shows considerable variation; the percentage of not using the RD ranges from as low as 11% to as high as over 90%.[3,5,7–21] Although surveys reported that almost all undergraduate students expected to use the RD in endodontics post-qualification,[3,19] RD use tends to decrease dramatically after graduation (Table 1). The number of years of professional activity after graduation may not contribute significantly to the attitude of the GDPs towards the application of RD. This has been proved by Swallow[7] who found that as high as 85–90% of GDPs had never or did not use the RD for >1 year regardless of the number of years of professional activity after graduation. Stewardson[11] also reported similar observations. Furthermore, Peciuliene *et al.*[20] observed that most GDPs with ≥10 years of clinical experience after graduation had never applied the RD. The situation was better with younger GDPs but the percentage not using the RD was almost 40% (Table 1).

Attitude towards rubber dam use

Undergraduate students

Dental schools worldwide teach the application of RD in restorative dentistry; however, Ryan and O'Connell[3] found that most undergraduate dental students are not convinced of the benefit of RD application in their dental practice except for endodontic treatment. And yet Mala *et al.*[19] reported that 90% of students felt that root canal treatments performed without a RD are not as successful as those isolated with a RD. Ninety-eight per cent of respondents believed that they would use the RD when carrying out root canal treatment. Surprisingly, the majority of students predicted their overall use of the RD would decrease after graduation. This emphasizes the need to enhance current teaching protocols to promote increased use of the RD whilst in general practice.

Reasons why undergraduate students are reluctant to use the RD include: (1) it is difficult to apply; (2) the time taken for proper placement; and (3) the belief that patients do not like it.[3,19] Although the time taken to apply the RD is about five minutes,[3,22] some students consider the placement of RD as 'wasted time' while they rush to finish their requirements necessary for graduation.[3] However, it is strongly believed the operator's experience in application time and duration of the RD plays an important role in patient satisfaction along with a greater preference for RD application during subsequent visits.[22]

General dental practitioners

As mentioned earlier, the prevalence of RD use by GDPs in different countries tends to decrease dramatically after graduation. New GDPs are not conversant with profitably managing a private practice and are outside the rules established within the educational environment of the dental school. Some GDPs and specialists may even place the RD clamp without the rubber sheet for only radiographic documentation/ publication. Nevertheless, it is believed that current students exposed to contemporary research and opinion may have a different approach to the use of RD after graduation compared with colleagues trained in previous decades.[19]

Factors affecting rubber dam use after graduation

Brookman[23] analysed vocational trainees' views of their undergraduate endodontic training to gain a better understanding of their knowledge after exposure to clinical practice. He found only 31% were using the RD routinely (none were using it in one dental school, while in another school, 82% were using it in practice). The same observation has been reported in a previous study.[9] This indicates that the teaching of RD application at undergraduate level may vary. Most non-users agreed they would use RD if they knew how to place it simply. Barnes *et al.*[24] reviewed the continuing professional development of dentists in Europe and found that 'learning needs identification and reflection on practice that was rarely evidenced'.

Decision-making in clinical practice results from a thorough analysis of current science. Evidence based practice is 'the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients'.[25] To achieve this goal, international organizations such as the Cochrane Collaboration aim to help people make well-informed decisions about health care by preparing, maintaining, and ensuring the accessibility of rigorous, systematic, and up-to-date reviews (and, where possible, meta-analyses) of the benefits and risks of health care interventions.[26] Iqbal and Glenny[25] described evidence based dentistry as the shift maker 'between clinical research and real world dental practice'. Therefore, it seems appropriate that GDPs request evidence to support requirements regarding application of the RD; however, peer-reviewed evidence is scarce.

Table 1. Summary on the prevalence of and attitudes to rubber dam use in endodontics

Author/s	Year	Country	Results				
Swallow[7]	1983	North Ireland (GDPs)		Used RD last month	Used RD last year	>year/never	
			1–10 years*	7%	8%	85%	
			11–20 years	7%	3%	90%	
			21–30 years	9%	5%	86%	
Saunders *et al.*[8]	1999	Scotland (GDPs)	24.9% routinely used				
Whiteworth *et al.*[9]	2000	North of England (GDPs/NHS†)		Younger graduates		Older graduates	
			Always/frequently				
			School A	17%		9%	
			School B	33%		18%	
			Never				
			School A	62%		66%	
			School B	44%		66%	
Ahmed *et al.*[10]	2000	Khartoum, Sudan (GDPs)	98%: Do not use 2%: Use				
Stewardson[11]‡	2001	UK (private and NHS)		GA	GB	GC	GP
			Always	4%	0%	5%	28%
			More often than not	8%	4%	11%	8%
			Occasionally	25%	23%	28%	40%
			Never	63%	73%	56%	24%
Koshy and Chandler[12]	2002	New Zealand (GDP)	57% use routinely				
Slaus and Bottenberg[13]	2002	Belgium (GDP)	Never: 77.3% Sometimes: 18.5% Always: 3.4%				
Stewardson and McHugh[22]§	2002	UK (Final year dental students (DSs) and GDPs)	Patients' future preference in relation to current experience:				
				+ve experience		-ve experience	
				DSs	GDPs	DSs	GDPs
			Yes	55%	80%	26%	35%
			No	45%	19%	43%	52%
			No Pref.	0%	1%	31%	13%
Hommez *et al.*[14]	2003	Belgium (dentists)	Never or seldom used: 64.5% Limited cases: 20.5% Used in all cases: 7.2% The time since graduation has no significant effect on use of RD				
Lynch and McConnell[15]	2007	Ireland (GDPs)		Anteriors	Premolars	Molars	
			Never (0%)	39%	32%	26%	
			Rarely (1–25%)	17%	14%	12%	
			Occasion (26–50%)	2%	6%	7%	
			Often (51–75%)	6%	2%	6%	
			Mostly (75–99%)	9%	14%	9%	
			Always (100%)	27%	32%	40%	
Ryan and O'Connell[3]	2007	Ireland (undergraduate dental students)	98.5% and 100% of students predicted the use of RD for post-qualification in endodontics in children and adults, respectively				
Hill and Rubel[16]	2008	USA (GDPs)	Never (Grade 1): 11% Grade 2: 5% Grade 3: 13% Grade 4: 13% Always (Grade 5): 58%				
Koch *et al.*[17]	2009	Sweden (GDPs)	66.67% always use RD 20% routinely use RD but made exceptions occasionally				
Palmer *et al.*[18]	2009	UK (GDPs)	Rubber dam used in all cases: 30.3% Rubber dam used in some cases: 37.4% Cotton wool rolls/butterfly sponges: 29% None: 3.3%				
Mala *et al.*[19]	2009	School of Dentistry, Cardiff (CAR), UK and Cork (COR), Ireland. (undergraduate students)		RCT in CAR (all teeth)		RCT in COR (all teeth)	
			Never (0%)	1.33%		3.67%	
			Rarely (1–25%)	1.33%		0%	
			Occasion (26–50%)	0%		3%	
			Often (51–75%)	0%		1%	
			Mostly (75–99%)	6%		8%	
			Always (100%)	91.33%		84.33%	
Peciuliene *et al.*[20]	2010	Lithuania (GDPs)		GA	GB	GC	GD
			Always/Often	35.8%	10.1%	1.9%	2.7%
			Sometimes/Occasion	26.6%	26%	25.2%	13.1%
			Never	37.7%	63.9%	73%	84.2%

(continued)

Table 1. *continued*

Author/s	Year	Country	Results
Lin *et al.*[21]	2011	Taiwan (Dentists under National Health Insurance)	Overall prevalence is 16.5% Hospitals: 32.8% Private practice: 10.3%
Anabtawi *et al.*[5]	2013	USA (GDPs)	RD never used for RCT: 15% RD used for 1–50% of RCT: 17% RD used for 50–99% of RCT: 24% RD used for all RCTs (100%): 44%

*Number of years after graduation.
†NHS: National Health Service.
‡Group A: new dentists (<5 years post). Group B: 5–15 years. Group C: >15 years. Group P: Private.
§This study included all treatment procedures.
¶Group A: Up to 9 years of professional activity. Group B: 10–19 years. Group C: 20–29 years. Group D: >30 years.

Why is evidence scarce in regards to RD usage in endodontics? Certainly clinical cohort studies could answer this question but researchers are confronted with an ethical dilemma. RD use is considered the gold standard and a control group treated without using RD would simply be unethical and inconceivable. Accordingly, the routine use of RD should not require a scientific investigation to persuade sceptical GDPs of the essential need for RD during endodontic therapy. Because endodontists have at least two additional years of specialty training following graduation from dental school with a broader and deeper body of knowledge, this difference probably explains why so many GDPs are less consistent with RD application.[27,28]

The main reasons for the negative opinion of GDPs towards RD application are difficult placement, time required for application, occasional patient complaints and cost.[8,10,15,29] In an attempt to overcome these drawbacks, other isolation techniques have been undertaken by GDPs during root canal treatment. In addition to cotton rolls and/or gauze, some authors and GDPs claimed that other isolation techniques such as Isolite (Benbrook Dental, USA) are able to enhance visibility, reduce the risk of damage of porcelain surfaces, minimize the risk of perforation and can be useful in young patients with incompletely erupted teeth.[5,30,31] Despite these claims, it is strongly believed that all the above-mentioned clinical situations can be managed with RD application (Table 2). More importantly, such devices will not protect the supporting gingivae from toxic irrigants (e.g. higher concentrations of NaOCl). Only RD can act as a safe and effective barrier, which can be applied adequately even with third molar teeth.[32] Few reports have documented the aspiration/ingestion of RD clamps.[33,34] However, by following the proper protocols, such procedural accidents are highly improbable (Table 2).

Patients

The majority of patients are not averse to RD application; indeed, they would even prefer RD for future appointments.[22] However, Mala *et al.*[19] found that 45% of undergraduate respondents reported patients did not like RD but the possibility of anecdotal reporter bias cannot be ignored. The most common positive comments about RD application are the absence of debris in the mouth and protection of the tongue. Patients' negative comments commonly include dribbling, difficulty to swallow and hypersalivation.[22] Usually, this negative attitude is attributed to lack of experience and skill, in addition to other issues such as limited communication. Basically, patients' satisfaction can be obtained only if the dentist is convinced of its value. The best way to improve patient acceptance of RD is to: (1) give concise and cogent explanations regarding the benefits of RD prior to commencing root canal therapy; (2) increase the skill of the GDP with more 'hands-on' training; and (3) reduce RD application time.

The rubber dam and dental-legal issues

Expanding the scientific evidence that supports our clinical endeavours is essential to provide the highest quality of care to our patients.[35] Because patient safety and clinical practice guidelines ensure a sterile and safe field for root canal treatment, it is unnecessary and unethical to consider a cohort study to prove what is already universally agreed upon.[4,36–38] Despite this, the positive impact of RD use on clinical outcomes, including retreatment cases, has been documented in the literature.[4,39]

It is incumbent upon GDPs to have the proper RD armamentarium, so it would be highly inappropriate for GDPs to consider some challenging cases too difficult for RD isolation due to an inadequate RD armamentarium. Dental floss, Wedjets™, stabilizing cords

Table 2. Common reasons for negative attitudes towards RD applications and how to manage them

Problem	How to manage
Insufficient training/time-consuming	– Periodic educational programmes for dental professions and dental assistants (continuing professional education) – Training in different clinical situations ranging from easy to difficult
Patient rejection	– Patient education – Minimizing the duration of application – Enhancing communication between the operator and patient during treatment via other means such as hand control – Mouth props to reduce muscle strains
Badly decayed tooth (supra or at the gingival level)	– Copper or orthodontic bands, build up the remaining tooth structure prior to treatment – Clamps with prongs inclined apically – Split-dam technique (if the tooth structure is at the gingival margin, a coloured adhesive material acting as a collar is preferred) – Canal projection technique
Badly decayed tooth (subgingival)	– Gingivectomy – Crown lengthening – Orthodontic extrusion
Incompletely erupted tooth/prepared tooth for crown with no apparent undercuts	A coloured compomer or composite can be applied on facial and lingual surfaces to create undercuts for placing the clamps
Leakage	– Hydrophobic caulking agents – Periodontal packing – Replacing the RD with another one
Cost of the RD	– Anterior teeth can be isolated via RD supported with rubber wedges – Surgical latex gloves can be used as RD
Fear of damage of porcelain crowns/veneers	– Split rubber dam – Wedjets and plastic rubber dam clamps
Fear of aspiration or ingestion of the clamp	Tie a dental floss through the holes of the clamp to prevent this occurrence
Deterioration of the breathing pattern	– Minimizing the duration of application – Venting the RD. Cutting a breathing hole in the RD in a place where leakage cannot occur

and hydrophobic non-setting caulking pastes would ensure optimum sealing, even in difficult clinical situations.[6,40] Split-dam technique can be used when there is insufficient tooth structure or in the presence of porcelain crowns or veneers. With the apparent increase of patients allergic to latex, it is essential that non-latex RD should also be available for the GDP.[40]

While most patients show a positive attitude towards RD application, some reluctant patients may resist its application. Despite this, there is no verbal or written consent that can justify the non-use of RD.[41,42] The GDP should spend the necessary time to explain the importance, safety and effectiveness provided with RD (Table 2). Indeed, the positive experience gained by the patient would create a future preference for root canal treatment using RD.

It is obvious there is no contraindication for RD placement in endodontic practice. Some authors have emphasized that particular care should be taken to avoid impinging on the gingival tissues during placement of RD clamps, especially in patients with a history of taking bisphosphonates,[43] and/or bleeding disorders. Indeed, the use of interdental wedges or stabilizing cords to place RD instead of metallic clamps is a reasonable and safe alternative. Some clinical situations, such as calcified pulp cavities or misaligned crowns may warrant special management.[44] In such cases, preparing the access cavity prior to RD application is recommended to avoid an iatrogenic problem (the RD is placed just before removing the roof of the pulp chamber).

In some cases, there is a risk that subgingival restorations used as proximal walls may block one of the exposed canal orifices after caries removal.[45] Slight coronal widening of the exposure site and inserting a conical piece of a plastic tube in the canal orifice followed by the application of the restorative material into the proximal area would prevent canal blockage prior to RD placement.[45] The same procedure can be applied to treat Class III invasive cervical resorption.

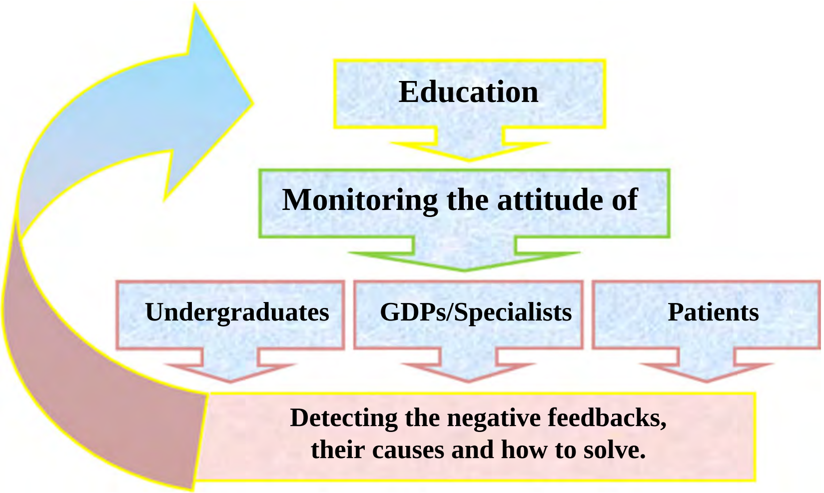

Fig. 1 Education plays an essential role in the attitude of dentists and patients towards the rubber dam. The negative attitude reported by dental students, general dental practitioners and patients should lead to enduring clinical protocols in the quality of education to ensure wide adoption of the rubber dam.

Some authors claim that commencing RCT *during* the surgical management of Class III invasive cervical resorption would avoid an accidental displacement of the cervical restoration during a second visit for root canal obturation.[46] However, in such treatment procedure, proper isolation cannot be achieved and there is a high possibility for contamination.

Directions for future research

Education via an interactive learning process gives undergraduate students the opportunity to learn in the clinical setting during the early stages of training. Exposure to the most current clinical research along with clinical guidelines in a relevant professional clinical context is essential.[47] Future studies to compare different interactive education programmes (i.e. comparing the education of RD use via dummy heads or a student-partner or both) are warranted to identify the best approach that would instil applying RD for all endodontic patients before *and* after graduation. Once an easy-to-replicate 'methods and materials' protocol has been developed, comparative studies and data analysis can be distilled into a successful undergraduate teaching model that will endure[19] (Fig. 1). We anticipate once this optimized teaching model is incorporated into the undergraduate clinical curriculum, the usual negative impediments will dissipate.

A prospective survey of undergraduate students up to five years after graduation would also aid in monitoring students' attitudes to RD use during root canal treatment[19] (Fig. 1). This would help to identify the specific reasons behind negative attitudes, which could then be followed up with suitable modifications to educational programmes to address these shortcomings.

DISCLOSURE

The authors confirm they have no financial interest or affiliation with materials discussed in this manuscript.

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Rubber Dam Use during Post Placement Influences the Success of Root Canal–treated Teeth

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Abstract

Introduction: Salivary leakage after root canal therapy is of great concern and can lead to failure of the endodontic therapy. The aim of this study was to investigate whether the use of a rubber dam (RD) during post placement impacts the success of root canal–treated teeth. **Methods:** Retrospective chart reviews of 185 patients with an average recall of 2.7 years were assessed for the incidence of a new periapical lesion (periapical index score >2) after root canal therapy and post placement. The patients were divided into 2 groups based on the presence or absence of an RD clamp in the verification radiograph during post placement. **Results:** Twenty-six patients (30 teeth) had a post placed with the use of an RD, and 159 patients (174 teeth) had a post placed without an RD. In the non-RD group, 128 (73.6%) teeth were considered successful at follow-up. In the RD group, 28 (93.3%) teeth were considered successful at follow-up. Based on the bivariate GEE model, the difference in success between these 2 groups was statistically significant ($P = .035$). **Conclusions:** The use of an RD during prefabricated post placement provides a significantly higher success rate of root canal–treated teeth. Using an RD is already considered a standard of care for nonsurgical root canal therapy; in addition, using an RD during restorative procedures that involve open teeth should also become a standard of care. *(J Endod 2013;39:1481–1484)*

Key Words

Endodontic therapy, prefabricated post and core, root canal treatment, rubber dam

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It has been long established that oral bacteria are responsible for pulpal and periapical disease (1) and are the primary etiologic factors associated with root canal failure (2–4). Salivary bacteria gain access to the root canal system through coronal leakage both while the tooth is restored temporarily and permanently (3). Although it has been shown that a well-obturated root canal helps to delay the recontamination of the root canal system (5), it is only a temporary barrier, and nearly the entire length of the root canal can be recontaminated within as short as 72 hours in the presence of coronal leakage (6, 7). This is the shortest time period tested, and it may be possible that significant contamination could be caused by coronal salivary exposure occurring in an even shorter time period.

During the process of post placement without the use of rubber dam isolation by dental practitioners, root canal–treated teeth are potentially exposed to saliva and subsequent microbial contamination. The lack of tooth isolation and an extended procedural time period, including radiographs and post space preparation, allow the patients to open and close their mouths, bathing the pulp chamber and root canal in saliva.

The use of a rubber dam (RD) is the standard of care for root canal treatment. According to the American Association of Endodontists position statement, "Tooth isolation is the standard of care; it is integral and essential for any nonsurgical endodontic treatment…only the dental dam isolation minimizes the risk of contamination of the root canal system by indigenous oral bacteria" (8). According to Ingle et al (9) in the Washington Study, a significant cause of root canal failure is inadequate cleaning and obturation of the root canal system, which leaves behind bacteria. The protocol followed for root canal therapy with the use of the RD can be negated once the restorative dentist exposes a recently cleaned and obturated root canal to indigenous oral bacteria during post placement without an RD.

To the authors' knowledge, the impact of coronal leakage during post placement has never been investigated, and it has become common practice for dentists and dental students to place a restoration after root canal therapy, including a post, without the use of an RD. Following an aseptic technique used during root canal therapy, the practitioner often abandons the use of the RD in favor of convenience, thus allowing contamination of the obturated pulp chamber and coronal aspects of the obturated root canals. The purpose of this study was to investigate whether the use of an RD in the placement of a prefabricated post and core impacts the success of root canal–treated teeth.

Materials and Methods

Institutional review board approval was obtained from Tufts University, Boston, MA. All electronic data were kept on a password-protected computer and were only available to the study investigators. Each subject was assigned a unique numeric identifier, which allowed coding of data for analysis. Data were queried based on American Dental Association codes for root canal treatment and post placement by Tufts University Department of Information Technology. No specific patient identifiers were collected. All research was conducted at Tufts University School of Dental Medicine (TUSDM).

Eight hundred forty-six patients treated at TUSDM undergraduate and postgraduate endodontic clinics during the period of 2008–2011 comprised the study population. During this period, root canal therapy was completed, and, subsequently, a prefabricated post and core was used to restore the tooth by an undergraduate dental student before crown placement. Because of the retrospective nature of this study, no attempts were made to standardize the techniques by which root canal therapy or obturation were completed. However, all treatment can be assumed to have been done with techniques being taught at the time, which included step-back hand instrumentation with lateral condensation for the patients treated before the fall of 2010 and rotary instrumentation with continuous wave vertical condensation after that time. All treatment, although it was performed by various providers, was supervised by experienced endodontic faculty and residents. Patient records from the Axium dental charting system (Exan Group, Coquitlam, British Columbia, Canada) were reviewed to assess the periapical status of the tooth at the time of post placement and again at a recall period of at least 6 months to 6 years.

Inclusion criteria included the following:

1. Records had to be available for patients who had root canal therapy completed by undergraduate and graduate students at TUSDM within the time period indicated.
2. The tooth did not have a periapical lesion or a widened periodontal ligament (PDL) greater than twice the width of an adjacent health PDL (periapical index [PAI] score 1 or 2 only) (10).
3. Only endodontic cases of good quality were selected for evaluation.

Good quality was defined as "all canals were obturated, no voids were present, and fill of the main gutta-percha point was within 0.0–2.0 mm from the radiographic apex" (11). Exclusion criteria were as follows:

1. Teeth with a periapical lesion as determined by the presence of periapical radiolucency beyond that of a widened PDL (>2× PDL width) at the time of root canal treatment and post placement (PAI 3–5)
2. Patients without a follow-up radiograph of at least 6 months
3. Teeth extracted within the first 6 months after root canal therapy
4. Cases in which procedural errors (perforation, separated file, and transportation) occurred during post placement that resulted in extraction or decreased prognosis
5. Teeth with development anomalies, immature roots, and crown or root fracture

The charts and radiographs of patients were reviewed to determine eligibility. For charts meeting the inclusion criteria, the following data were recorded:

1. The presence of an RD clamp in the post placement verification radiograph, thus indicating the use of an RD during post placement (Fig. 1)
2. The presence or absence of periapical radiolucency upon the most recent recall examination not to be less than 6 months after post placement

The presence of periapical radiolucency, a PDL space wider than 2 times its normal width, or evidence of extraction at the time of recall, was determined as treatment failure.

Data collection was completed by 2 of the authors. The determination of a pre- and postoperative lesion was determined at the time of data collection and also by a third observer. The third observer was blinded to whether or not an RD was used by blocking out the coronal portion of the radiograph at the time of evaluation. All radiographs were projected to approximately 2 × 1.5 ft on a 9-foot screen and viewed under darkened lighting conditions. All disagreements were resolved by discussion among the 3 clinician investigators; if no consensus was reached, the tooth was excluded from analysis.

The follow-up radiographs were collected at the time of data collection and later evaluated for the presence of a postoperative lesion. At the time of the evaluation, none of the observers were aware of the RD isolation status of the follow-up radiograph being evaluated.

Statistical Analysis

A power calculation was conducted using nQuery Advisor (Version 7.0; Statistical Solutions, Saugus, MA). Assuming a 91% survival rate in the RD group and a 44% survival rate in the non-RD group (11), a sample size of at least 20 patients with an RD post placement and at least 100 patients with a non-RD post placement was determined to be adequate to obtain a type I error rate of 5% and a power greater than 90%.

Descriptive statistics (counts and percentages for categoric variables and means and standard deviation [SD] for continuous variables) were calculated. To account for the existence of multiple treatments on the same patient, statistical significance was assessed via generalized estimating equations (GEEs). A bivariate GEE model was used to test the association between the type of placement (RD or no RD) and success. A multivariate GEE model was also run to adjust for the number of years to follow-up. P values <.05 were considered statistically

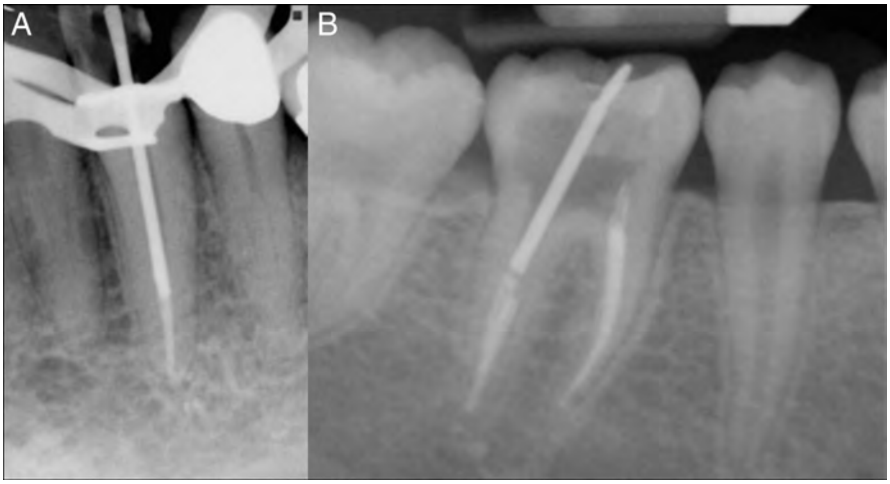

Figure 1. A typical post verification radiograph showing the (*A*) presence and (*B*) absence of an RD clamp. This is an example of a case that was included in the RD group.

significant. SAS Version 9.2 (SAS Institute, Cary, NC) was used to analyze the data.

Results

Charts were reviewed until a sufficient number of patients were obtained to satisfy the power analysis. One hundred eighty-five patients (204 teeth) met the inclusion criteria for the study. Recall ranged from 6 months–5.75 years (average = 2.7 years, SD = 1.5). Twenty-six patients (30 teeth) received at least 1 post placed with the use of an RD, and 159 patients (174 teeth) received at least 1 post placed without RD isolation (Table 1). Only 1 patient fell into both groups. The average age of the study population was 58.5 years (SD = 15.6 years). The average age of the RD group was 53 years (SD = 17.9); the average age of the non-RD group was 59.4 years (SD = 15.1). There was no statistically significant difference in age between the 2 groups.

Of the 174 teeth treated without the use of an RD, 128 (73.6%) were considered a success at the time of their final radiographic follow-up. Of the 30 teeth treated with the use of an RD, 28 (93.3%) were considered a success at the time of their final radiographic follow-up. Based on the bivariate GEE model, there was a statistically significant difference between the success rate when an RD was used during post placement (P = .035). When the model was adjusted for the number of years to follow-up, there was still a statistically significant difference in success rate based on the use of an RD (P = .035); however, there was no statistically significant association between follow-up time and success (P = .652).

Discussion

A minimum recall time of 6 months was chosen to permit sufficient time for radiographic and clinical signs and symptoms of failure to become apparent (12, 13). Animal models in monkeys have shown that periapical breakdown will become visible by 6 months in infected root canals (14). A maximal recall of 6 years was chosen because digital radiographs were implemented in 2007 and the authors were not able to access paper charts before this time.

The results of this study emphasize the importance of a quality aseptic technique in restoring root canal–treated teeth to preserve an uncontaminated environment within the root canal system. Salivary contamination results in oral pathogens being sealed within the pulp chamber. These bacteria then feed on the breakdown products of the bonded restorative materials, leading to coronal leakage and sustained bacterial contamination (15, 16). Coronal leakage and salivary contamination within the root canal system contribute to failure more often than an inferior technical quality root canal procedure (11). Specifically, a well-obturated tooth with a poor and presumably leaking coronal restoration has a survival rate of 44%, whereas a radiographically well-sealed restoration regardless of the quality of the root canal therapy provided an 80% survival rate. If we only consider good quality root canal therapy, the survival becomes over 91% (11). In addition, *in vivo* and *in vitro* leakage studies (6, 7) have shown that coronal leakage of saliva significantly contaminates nearly the entire length of the root canal system in as little as 72 hours.

It is common practice to leave at least 5–7 mm of gutta-percha apically during post space preparation to preserve an adequate apical seal. Removal of gutta-percha beyond this level has been shown to significantly increase the susceptibility to leakage (17). Furthermore, removal of gutta-percha to a level of 6 mm has been shown to lead to an unpredictable and significantly inferior seal compared with an intact root canal filling (18). The uncertain quality of the compromised apical seal as a result of gutta-percha removal during post space preparation leads to an even greater concern for the occurrence of salivary contamination. For this reason, during post space preparation and post placement, an RD should be used.

TABLE 1. Outcomes for Post Placement with and without the Use of an RD

	Total (n)	Lesion on follow-up	Success (PAI $\leq$2)	Success (%)
No rubber dam	174	46	128	73.6
RD	30	2	28	93.3

PAI, periapical index; RD, rubber dam.

Both step-back hand instrumentation with lateral condensation and rotary instrumentation with continuous wave vertical condensation were used to treat patients in this study; however, no attempt was made to differentiate between which technique was used for each patient. Some studies suggest the type of instrumentation or obturation has no significant impact on the outcome of root canal treatment (19, 20), whereas other studies show that the type of instrumentation and obturation significantly impacts the outcome (21). Despite this observation, no differentiation was made between data samples taken in this study. This may be assumed to be a shortcoming of this study.

Given the limited availability of data for teeth treated with the use of an RD, this bias could not be avoided while obtaining a large enough data sample. This provides an opportunity for future research; however, a prospective study with a larger sample size and more controls of both bias and additional variable is warranted. The authors warn against drawing too many unwarranted conclusions from this article and recommend that it be used as the basis for future research on this topic.

To establish success in root canal–treated teeth, radiographic assessment and interpretation may be graded using a PAI score (22). A modified PAI score can be used when the tooth in question is free of a periapical lesion at the time of obturation. Therefore, a tooth that begins the observation period with a normal or widened PDL can only be ruled an absolute failure based on the development of a new frank periapical lesion (PAI > 2) (22). In the presence of an intact lamina dura and PDL space less than 2 times the width of adjacent healthy PDL space, the root canal therapy can be declared a success at the end of the observation period. Additionally, to remove confounding factors of inter- and intraobserver agreement as to the healing extent of an existing lesion, only teeth free of an existing preoperative lesion should be included. It has been well established that the interpretation of radiographs can be inconsistent (23).

The results of this study support previous findings that coronal contamination of the pulp chamber with salivary fluids in root canal–treated teeth decreases the long-term prognosis. The results further emphasize the importance of RD isolation and aseptic techniques in the restoration of these teeth. It was also observed that only 26 of 185 patients (14%) had an RD used during post placement. Given that dental school faculty do not emphasize its use, it is unlikely that upon graduation dental students will incorporate this technique into their dental practice. It is imperative that the importance of RD use is emphasized as a critical component of dental education.

Conclusion

During prefabricated post placement, it was found that the success rate of the underlying endodontic treatment was significantly enhanced when an RD was used. Further studies need to be done to advance the knowledge about this important finding.

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RESEARCH REPORTS

This study evaluated the rubber dam as an infection control barrier during standard restorative procedures. Microbial collection was performed during preparation and placement of amalgam and composite resin restorations with and without the rubber dam, and during handpiece and air-water syringe spraying with and without the rubber dam. The results showed a significant reduction in microorganisms with the use of the rubber dam—70% to 88% and 95% to 99%, respectively; and 90% to 98% when all data were combined. These results indicate that using the rubber dam is a method of reducing microbial contamination at the primary source. Used with gloves, mask, and protective eyewear, the rubber dam provides an excellent barrier to the potential spread of infectious disease in the dental office.

The efficacy of the rubber dam as a barrier to the spread of microorganisms during dental treatment

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Several reports in the early 1960s expressed concern that the salivary aerosol particles and splatter generated during dental procedures may create a health problem for the dental team.[1-4] Aerosol particles generated during dental treatment range in size from 1.3 to 7.0 μm. Particles smaller than 5.0 μm can enter the airway and penetrate to the terminal bronchioles and alveoli of the lungs. Because they are minute, these particles are invisible to the human eye and can remain airborne for an extended period. They can rapidly circulate throughout an entire dental office via the forced-air heating system.[5] Splatter droplets are much larger than aerosol particles ($\geq$ 50 μm in diameter). Because they possess sufficient mass and are often generated at high speeds, splatter material can act as projectiles. Both aerosol particles and splatter droplets can contaminate the skin and mucous membranes of the mouth, nose, or eyes of dental office personnel. In addition, they can spread contamination onto the inert surfaces found throughout the operatory. Both aerosol and splatter particles can contain infectious agents as the diameter of a bacterial cell is about 1.0 μm and that of a virus is much smaller.

In 1963, Miller and others[6] proved that various dental procedures including prophylaxis cup polishing, use of the air turbine with water spray, and polishing restorations with a bristle brush, generated salivary particles containing various levels of microorganisms. Other studies[7-12] have confirmed these findings, and have shown that dental procedures generate bacteria-laden aerosol particles that contaminate the air, face, and eyes of both the patient and dental professional working at normal distances. During cavity preparations on patients with active tuberculosis, *Mycobacterium tuberculosis* was found in aerosol particles generated by the high-speed handpiece 4 ft from the patient's mouth.[13]

Studies on procedures that reduce microbial contamination from dental aerosol particles and splatter have shown varying degrees of success with the rubber dam,[3,6] preoperative mouthrinses,[7,14-15] toothbrushing,[16] and high-volume evacuation.[17] Two of these studies conducted in 1963[3,6] assessed the rubber dam and reduction of microbial contamination. One[3] used the air turbine handpiece in the mouths of four subjects during which time, petri dishes were exposed to the expelled salivary/water particles for 15 seconds at a distance of 11 in from the patients' mouths.[3] In two of the four patients, use of the rubber dam with the water spray and evacuation produced large reductions in microbial counts compared with the same procedure without the rubber dam. Consistently low bacterial counts were found with all four patients when the rubber dam was used without water but with supplemental evacuation. In the second study of six to ten patients,[6] polishing a restoration with a bristle brush with and without the rubber dam resulted in more than a 90% reduction in the number of microorganisms at 8-10 in from the patients' mouths.

Current information regarding infection control in the dental office has made it mandatory for the dental team to use effective barrier techniques including gloves, masks, and protective eyewear. In many instances, however, little emphasis is placed on the use of the rubber dam. This study reevaluated the rubber dam as an adjunctive infection control barrier for full-length restorative procedures in the dental office.

Methods and materials

This study is divided into two parts: part one involved microbial sampling

Fig 1 ■ Collection system of four petri dishes mounted 24 in from the patient's mouth and one plate on the patient's chest.

during the preparation and placement of dental restorations. In part two, sampling was taken while areas of the mouth were sprayed alternately with an air-water syringe and the spray from a high-speed handpiece. The second portion of the study primarily determined any differences in readings that might be attributed to microorganisms from the carious lesions themselves.

For the first part of the study, adult subjects who required restorations on adjacent anterior or posterior teeth were selected from the active patient pool at Indiana University School of Dentistry. A total of 16 patients participated in the first part of the study; four needing restorations in the maxillary posterior, four in the mandibular posterior, four in the maxillary anterior, and four in the mandibular anterior teeth. During the past 6 months none of the subjects had received a dental prophylaxis nor any antibiotic therapy.

Posterior teeth were restored with amalgam and anterior teeth with composite resin. Currently accepted procedures for cavity preparation, cleaning, basing and lining, enamel conditioning and manipulation, and placement of materials were followed, and all clinical procedures were performed by the same clinician. Adjacent lesions were restored at appointments at least 1 week apart. One lesion of each pair was restored using rubber dam isolation and high-volume evacuation; the other was restored using cotton roll isolation and high-volume evacuation. Selection of isolation method, lesion, and appointment was randomized. Aerosol particle sampling as described here was done during preparation, cleaning, and restoration of all lesions, and the time required was recorded.

All clinical procedures were performed in a closed operatory separate from other clinical facilities to minimize aerosol particle contamination of the environment. Sterile handpieces, air-water syringe tips, burs, rubber dam retainers, and hand instruments were used throughout the study, as were currently accepted barrier techniques (mask, gloves, and eyewear). Before each appointment, the handpiece and air-water syringe lines were flushed for 30 seconds and then sprayed into sterile glass containers for 30 seconds. This water was subsequently quantitatively cultured for the presence of bacteria.

For the second part of the study, ten patients were selected who met the same criteria for dental prophylaxis and antibiotic therapy, but who did not require any restorative procedures. Five patients were assigned as maxillary and five as mandibular. Patients were instructed not to brush or floss the day of their appointments.

At appointments at least 1 week apart, the area from second molar to opposite canine in each patient's assigned arch was sprayed for 2 min with a high-speed handpiece spray followed by 2 min with spray from an air-water syringe. This sequence was then repeated for 8 min of spraying. During the procedure, the sprays were moved slowly over the facial, occlusal/incisal, and lingual surfaces of the teeth. During one appointment, the teeth were isolated with the rubber dam, and at the other, with cotton rolls. High-volume evacuation was used at both appointments. Selection of isolation method was randomized. All other procedures outlined in part one were followed in part two.

Microbial analysis of aerosol particles and splatter

Microorganisms present in aerosol particles and splatter generated during patient treatment of parts one and two of this study were collected on a specially designed petri dish culture system (Fig 1). The system consisted of a board to which four 100- × 15-cm petri dishes containing agar (MM10) could be attached in a horizontal row by Velcro connections. The board with the four culture dishes was attached to the dental operating light and positioned directly perpendicular to and 24 in away from the patient's mouth during all procedures. Another petri dish containing the same kind of agar was placed on the patient's napkin 6 to 7 in from the patient's chin. Controls consisted of sets of four dishes attached to the dental light and one dish on the bracket table, all exposed to the air (with no patient present) for the same time required for patient treatment.

All culture dishes were incubated for 5 days at 37 C in an atmosphere of 85% N_2, 10% H_2, and 5% CO_2, and then in air at 37 C for 24 hours. The total number of colony-forming units (CFU) per each set of five dishes was determined by counting with a stereo microscope. Representatives of each colony type on each dish were analyzed for gram-stain reaction and morphologic cell structure. The number of CFUs on control dishes was subtracted from that of respective experimental dishes, and the data expressed as total CFUs per procedure. The respective means from the posterior mandibular restorations, posterior maxillary restorations, anterior mandibular restorations, anterior maxillary restorations, and the maxillary and mandibular quadrant spraying were calculated. The means with and without the use of the rubber dam were compared and the percent reduction in CFUs in different areas of the mouth was calculated. In addition, the means of combined maxillary data, combined mandibular data, and all data were calculated with and without use of the rubber dam and the percent reductions compared. Statistical analysis was conducted using the Mann-Whitney rank order *U*-test.

Contamination of the dental unit water lines was monitored from the handpiece and air-water syringe spray collections, which were plated on agar (MM10) and incubated under identical conditions to the collection petri dishes.

Results

The results of the study are shown in Table 1. The percent reduction in CFUs during cavity preparation and restoration with the rubber dam (from the areas where microbial contamination registered) ranged from 95% to 100% at the collection site 24 in from the mouth, and from 70% to 88% at the collection site on the patients' chests. The percent reduction in CFUs during spraying with handpiece and air-water syringe (using the rubber dam) ranged from 87% to 94% at the collection site 24 in from the mouth, and from 95% to 99% at the collection site on the patients' chests. Combined data for all sites produced a 90% to 98% reduction with the rubber dam. The Mann-Whitney rank order *U*-test was used to compare the microbial recovery data with and without rubber dam use (Table 2). Significant differences at the 0.05 level of confidence were found in all cases except for mandibular preparations/restorations at the collection site on the operating light. Although the number of CFUs was below statistical significance at the more distant collection site in these cases, reduction in CFUs was still consistent with all patients when the rubber dam was in place. The reductions at the chest site were all statistically significant.

Contaminants were periodically detected at varying concentrations in the waterlines of the dental unit used in the study. Such contaminants were always gram-negative rods. In contrast, the colonies found on the experimental dishes, both at the dental unit light and on the patients' chests with or without the use of rubber dam, were gram-positive cocci or rods and gram-negative cocci on 96% to 98% of all plates analyzed for the entire study. When gram-negative rods were detected on experimental dishes, their numbers were subtracted from the total dish counts before recording the results presented in Table 1. Some of the gram-negative rods that appeared on experimental dishes could have come from the mouth; however, all such colonies were subtracted from the counts to eliminate possible skewing of the results from the presence of waterline contaminants.

Table 1 ■ Recovery of microorganisms with and without the rubber dam during cavity preparations.

Procedure site	At dental unit light: Without dam (mean CFUs)	At dental unit light: With dam (mean CFUs)	At dental unit light: Reduction (%)	Patient's chest: Without dam (mean CFUs)	Patient's chest: With dam (mean CFUs)	Patient's chest: Reduction (%)
Actual cavity preparation*						
Maxillary anterior	41 ± 31†	0	100	211 ± 32	42 ± 18	80
Mandibular anterior	1 ± 0.5	0	100	120 ± 107	15 ± 9	88
Maxillary posterior	21 ± 11	1 ± 1	95	381 ± 210	84 ± 15	78
Mandibular posterior	0	0	. . .	36 ± 19	11 ± 7	70
Simulated study‡						
Maxillary	17 ± 9	1 ± 0.6	94	> 500	23 ± 12	> 95
Mandibular	3 ± 0.8	0.4 ± 0.4	87	> 356	5 ± 1	> 99
Combined data						
All maxillary	26 ± 10	0.5 ± 0.3	98	375 ± 68	48 ± 10	87
All mandibular	1.3 ± 0.3	0.2 ± 0.2	85	185 ± 59	10 ± 3	95
All sites	13 ± 0.3	0.3 ± 0.2	98	280 ± 39	29 ± 7	90

* n = 8 for each site.
† Mean CFUs ± standard error of the mean.
‡ n = 5 for each site.

Table 2 ■ Statistical significance of the reduction in aerosolized bacteria observed with the rubber dam (Mann-Whitney Rank Order *U*-test).

Procedure site	Bacteria sampled at dental unit light (*P* values)	Bacteria sampled at patient's chest (*P* values)
Actual cavity preparation		
Maxillary anterior	.014	.014
Mandibular anterior	NS*	.029
Maxillary posterior	.029	.029
Mandibular posterior	NS*	.029
Simulated study		
Maxillary	.008	.008
Mandibular	.008	.004
All maxillary	.001	.0001
All mandibular	.032	.001
All sites	.0001	.0001

*NS = not significant at the 0.05 level of confidence.

Because the microbial collection occurred throughout the entire cavity preparation and restoration procedures in the first of the study, comparison of the culturing data with and without use of the rubber dam would be best if the procedure times were similar. Table 3 presents the mean procedure times for all preparations/restorations at each of the four test sites. Analysis indicated that these times with and without use of the dam did not differ significantly. Therefore, the culturing data with and without use of the rubber dam at each test site would be comparable with respect to time.

Discussion

The results of this study are comparable to those of other studies on the barrier efficiency of the rubber dam conducted 25 years ago.[3-6] The earlier studies demonstrated reductions in airborne contamination 8-11 in away from

Table 3 ■ Mean procedure time during cavity preparations.

Procedure site*	Without dam (min)	With dam (min)
Maxillary anterior	11.8 ± 0.9†	13.5 ± 1.4
Mandibular anterior	10.5 ± 0.9	11.0 ± 0.9
Maxillary posterior	23.8 ± 1.1	21.8 ± 2.06
Mandibular posterior	16.0 ± 1.5	16.0 ± 1.7

* n = 4 min for each site with dam and 4 min without dam.
† Standard deviation.

patients' mouths, whereas the present study demonstrated similar reductions even at 24 in from the mouth. Previous studies used short sample collection times of 15 seconds during the use of the air turbine handpiece,[3] whereas the present study involved collecting the microbial sample throughout the entire restorative (11.8 to 23.8 min) or spraying (8 min) procedures.

High-volume evacuation was used in all instances in this study, and the results indicate that considerable contamination is still generated when evacuation without the rubber dam is used. However, the limited number of CFUs reaching the plates 24 in from the mouth indicates that high-volume evacuation may help limit the spread of aerosol particles. This study did not investigate the effects of evacuation alone, as evacuation is common with or without use of rubber dam.

In this study, the differences in the levels of microbes detected on dishes positioned on the patients' chests and those positioned 2 ft away on the dental light, reflect a greater concentration of airborne microbes closer to the patients' mouths. These results were not unexpected as the larger salivary droplets generated during dental procedures settle rapidly from the air and would heavily contaminate dishes on a patient's chest.

The variability in CFUs demonstrated by relatively high standard errors of the means probably resulted from the variability in the numbers of oral microbes originally present in the patients' mouths. Care was taken to standardize the microbial collection and culture procedures, and in controlling environmental contamination on the dishes. Nothing could be done about quantitatively controlling the level of microbes in the patients' mouths, which can vary considerably among individuals and between sites in the same mouth. Nevertheless, the overall percent reduction that was observed with the rubber dam suggests its efficacy for reducing cross-contamination from dental aerosols and salivary splatter.

Conclusions

The results of this and previous studies indicate that routine use of the rubber dam, combined with the other accepted barrier techniques, can contribute significantly to the overall dental office infection control program. Three factors determine if an infectious disease will develop: the disease-producing potential of the microbe involved; the dose of the microbe that contaminates the person; and the resistance of the person to the microbe involved. The practitioner cannot lessen the disease-producing potential of microbes nor make his or her body resistant to microbes in patients' mouths without vaccination (unless a vaccine such as that for hepatitis B is available). Thus, major efforts in office infection control must be directed toward reducing the dose of microbes that contaminate the body and operatory surfaces.

In the dental operatory, the primary source of potentially dangerous microbes is the patient's mouth. Reducing the amount of microbes spread from a patient's mouth during dental procedures attacks the problem of cross-infection and environmental contamination at the source. Routine infection control barriers (gloves, mask, and protective eyewear) and disinfection/sterilization procedures are mandatory in today's dental practice and have received widespread acceptance from the profession. Meanwhile, the use of the rubber dam is often ignored or deemphasized. The rubber dam offers an adjunctive method of reducing the spread of infectious disease agents in the dental office and, more importantly, provides barrier protection at the source of microbial contamination.

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The Effect of Rubber Dam Usage on the Survival Rate of Teeth Receiving Initial Root Canal Treatment: A Nationwide Population-based Study

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Abstract

Introduction: It is well-known that the usage of rubber dams during root canal treatment (RCT) improves infection control and treatment efficacy and protects patients. However, the effect of rubber dam usage on endodontic outcomes remain uncertain. The aim of the present study was to investigate whether rubber dam usage affects the survival rate of initial RCT using a nationwide population-based database. **Methods:** A total of 517,234 teeth that received initial RCT between 2005 and 2011 met the inclusion criteria and were followed until the end of 2011. Univariate and multivariate Cox proportional hazards models were used to estimate the effects of rubber dam usage on the risk of tooth extraction after initial RCT. **Results:** Of the 517,234 teeth, 29,219 were extracted, yielding a survival rate of 94.4%. The survival probability of initial RCT using rubber dams after 3.43 years (the mean observed time) was 90.3%, which was significantly greater than the 88.8% observed without the use of rubber dams ($P < .0001$). After adjusting for age, sex, tooth type, hospital level, tooth scaling frequency per year after RCT, and systemic diseases, including diabetes and hypertension, the tooth extraction hazard ratio for the RCT with rubber dams was significantly lower than that observed for RCT without rubber dams (hazard ratio = 0.81; 95% confidence interval, 0.79-0.84). **Conclusions:** The use of a rubber dam during RCT could provide a significantly higher survival rate after initial RCT. This result supports that rubber dam usage improves the outcomes of endodontic treatments. *(J Endod 2014;40:1733–1737)*

Key Words

Initial root canal treatment, rubber dam, survival analysis, survival rate

The aim of root canal treatment (RCT) is to save the patient's natural tooth from extraction and maintain the tooth's health and function. To achieve this goal, dentists perform a series of procedures that include eliminating microorganisms from within the root canal system and then sealing the canal space with adequate filling material. During treatment, it is important to isolate the treated tooth from the surrounding oral environment to control the possibility of cross infection and to create an aseptic operating field so that the treatment outcome will be promising. Therefore, the use of a rubber dam during RCT is highly recommended and has been regarded as standard care by professional organizations (1, 2).

The rubber dam was introduced to the dental practice in 1864 (3). Three major advantages of rubber dam usage during root canal treatment include improved infection control, patient protection, and greater treatment efficacy (4). Although the benefits are understandable and pronounced, the prevalence of rubber dam usage in Taiwan is only 16.5% (5). In contrast, the relative effectiveness of rubber dam usage on the endodontic outcomes remains uncertain.

In 1992, Gutmann (6) defined the success or failure of endodontic outcomes using clinical, radiographic, and histologic factors that focused on the periapical status of the treated tooth, such as periapical healing and post-treatment disease, to determine whether the ultimate goal of endodontic treatment had been achieved (1). Additionally, tooth survival rates and tooth retention rates have been suggested as alternative measured for the evaluation of RCT outcomes (7–11). Although the survival rate does not accurately reflect the prognosis of endodontic treatment, it is useful for epidemiological studies to compare the outcomes of various treatment modalities (12). The aim of the present study was to investigate whether rubber dam usage affects the survival rate of initial RCT using a nationwide population-based database.

Materials and Methods

Study Database

The Taiwan National Health Insurance program, which provides health care through compulsory health insurance and covers nearly 99% of the nearly 23.5 million residents of the Taiwanese population, began in 1995. Our study database used the records of the Longitudinal Health Insurance Database 2005, which spans from 2001–2011, and included the registration and medical claims of 1,000,000 randomly sampled patients from the total number of National Health Insurance beneficiaries in 2005. There were no statistically significant differences in age and/or sex between the sampled group and the entire set of enrollees. Many researchers have published

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endodontic articles that have used this database to conduct longitudinal and epidemiological studies (9, 10, 13).

Study Population

We included all of the teeth that had received initial RCT from 2005–2011 that were in the Longitudinal Health Insurance Database 2005 (90001C for 1-canal system, 90002C for 2-canal system, 90003C for 3-canal system, 90019C for 4-canal system, and 90020C for 5-or-more canal system). The retreatment cases were identified by a specific treatment code (90094C) during RCT, and those cases that were previously treated between 2001 and 2004 were excluded. Each tooth was followed from the completion date of its endodontic procedure until the end of 2011, which produced a maximum follow-up period of 7 years. The teeth that were extracted after RCT during the follow-up period were identified by the specific treatment codes for simple or complicated tooth extraction (92013C, 92014C, 92015C, and 92016C). This study was approved by the Institutional Review Board of Taipei Veterans General Hospital (approved number: 2012-12-009BCY).

Rubber dam usage was identified by a specific treatment code (90012C) during each endodontic session. The claiming of this code requires supporting evidence such as a periapical radiographic film or a clinical photograph. "Good" treatment quality was also identified by specific treatment codes (90095C, 90096C, and 90097C) in the database during the endodontic sessions, and this designation demands both an adequate filling length and dense and complete obturation in the apical third of the root canal (14). The diagnoses of the teeth that received RCT were made according to the *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*). Teeth without endodontic diagnoses (*ICD-9-CM*: 522.0–522.9) were excluded. The urbanization level of the residences and monthly incomes of the patients were also retrieved from the database to determine the socioeconomic status of each patient. The urbanization levels were categorized into 7 clusters based on the Taiwanese census data from 2000 (15).

Additionally, we considered several systemic diseases, including diabetes mellitus (*ICD-9-CM*: 250, including types I and II), hypertension (*ICD-9-CM*: 401–405), coronary artery disease (ICD-9-CM: 411–414), and hyperlipidemia (*ICD-9-CM*: 272), that were associated with tooth extraction in our analytic model (13, 16). To ensure the accuracy of the data accuracy, cases were included only when the patients had been given their diagnoses 3 or more times during outpatient visits or once or more during inpatient services in each year.

Statistical Analyses

The demographic and clinical characteristics of the patients whose teeth received RCT were analyzed with Student *t* tests and Mantel-Haenszel chi-square tests for the differences between the teeth that receive initial RCT with a rubber dam and those that received RCT without a rubber dam. Univariate and multivariate Cox proportional hazards models were used to estimate the effect of rubber dam usage on the risk of tooth extraction after RCT during the period from 2005–2011. Potential confounding factors, such as age, sex, tooth type, hospital level, tooth scaling frequency per year after RCT, and systemic diseases, were adjusted in the Cox regression analyses. All statistical tests were performed using SAS 9.2 software (SAS Institute Inc, Cary, NC), and the level of significance was set at $P < .05$ (2-tailed).

Results

A total of 517,234 teeth matched the inclusion criteria in the time period of 2005–2011 (mean observed time = 3.43 years); 29,219 of these teeth were extracted, which yielded an overall survival rate of 94.4%. The survival rate of the teeth that received RCT with a rubber dam was 95.15% (73,728/77,489), which was significantly higher than the 94.21% (414,287/439,475) that was observed for the teeth that received RCT with a rubber dam (Table 1, $P < .0001$). Table 1 shows the distributions of the demographic and clinical characteristics for the teeth that received RCT during the period of 2005–2011. The older patients had undergone a greater number of RCTs without the use of rubber dams ($P < .0001$). Molars were more likely to undergo treatments that involved rubber dams compared with anterior teeth and premolars ($P < .0001$). A greater percentage of the RCTs that were performed in hospitals, including medical centers, regional hospitals, and district hospitals, used rubber dams compared with those that were performed in local clinics. The patients who received RCT with rubber dams were more likely to have diabetes, hypertension, coronary artery disease, and hyperlipidemia than were those who received RCT without rubber dams (all $P < .0001$).

Figure 1 shows the cumulative survival probabilities for the teeth that received RCT during 2005–2011 segregated by rubber dam usage. The survival probability of RCT that used rubber dams after 3.43 years (the mean observed time) was 90.3%, which was significantly higher than the 88.8% observed among those that did not use rubber dams ($P < .0001$, log-rank test). Cox proportional hazards regression analysis showed that the crude hazard ratio (HR) for tooth extraction was 0.89 times lower for the teeth that received initial RCT with a rubber dam (95% confidence interval [CI], 0.86–0.92, $P < .0001$) than for the teeth that underwent RCT without a rubber dam. After adjusting for potential confounding factors that included age, sex, tooth type, hospital level, tooth scaling frequency per year after RCT, and systemic diseases, including diabetes and hypertension, the adjusted HR for tooth extraction for the teeth that received RCT with a rubber dam was 0.81 (95% CI, 0.79–0.84), which was significantly better than that for the teeth that received RCT without a rubber dam ($P < .0001$, Table 2). Multivariate Cox proportional hazards regression analyses indicated that the effect of rubber dam usage results in a significantly higher survival rate at 3.43 years after initial RCT.

Discussion

The present study explored the effect of rubber dam usage on the survival rate of the teeth that received initial RCT from 2005–2011; 517,234 teeth were analyzed, and the overall survival rate was 94.4%. This rate is similar to those reported in other epidemiologic surveys that have used insurance records. Lazarski et al (7) reported a 94.44% survival rate for nonsurgical RCT teeth that remained functional over an average follow-up time of 3.5 years. Salehrabi and Rotstein (8) reported that 97% of teeth survived for 8 years after primary nonsurgical RCT. Finally, using the same database as ours, Chen et al (9) reported a survival rate of 92.9% at 5 years after nonsurgical RCT. These studies indicate that RCT is a valuable dental procedure because of the high survival rate.

The present study found a relatively low rubber dam usage prevalence (15.0%) in Taiwan. This result is similar to that of the study by Lin et al (5) in 2011 that used data from 2004 that were extracted from Taiwan's National Health Insurance Research Database (NHIRD). These authors reported a rubber dam usage prevalence of 16.5% (5). Rubber dam usage during RCT provides an aseptic operating field that can prevent contamination from blood and saliva, improve visibility by retracting soft tissues and isolating the tooth, minimize conversation with the patient to improve treatment efficiency, and protect the patient from swallowing or aspirating instruments into their gastrointestinal or respiratory tracts (4). Furthermore, rubber dam usage might be associated

TABLE 1. Demographic and Clinical Characteristics of the Patients in Taiwan's National Health Insurance Research Database Whose Teeth Received Initial Root Canal Treatment (RCT) between 2005 and 2011

Variables	RCT with rubber dam (n = 77,489)		RCT without rubber dam (n = 439,745)		
	N	%	*N*	%	*P* value
Average observed time (mean [standard deviation], months)	39.29 (24.26)		41.44 (24.22)		<.0001
Tooth extraction					<.0001
Yes	3761	4.85	25,458	5.79	
No	73,728	95.15	414,287	94.21	
Sex					.38
Female	44,019	56.81	249,059	56.64	
Male	33,470	43.19	190,686	43.36	
Age (year)					<.0001
≤20	6631	8.56	36,910	8.39	
21–40	29,575	38.17	135,399	30.79	
41–60	29,590	38.19	178,071	40.49	
>60	11,693	15.09	89,365	20.32	
Treatment quality					<.0001
Good	10,806	13.95	0	0.00	
Average	66,683	86.05	439,745	100.00	
Tooth type					<.0001
Anterior	15,512	20.02	134,946	30.69	
Premolar	24,601	31.75	139,174	31.65	
Molar	37,376	48.23	165,625	37.66	
Diagnosis of RCT					<.0001
Pulpitis (5220)	59,941	77.35	374,438	85.15	
Pulp necrosis (5221)	7971	10.29	37,226	8.47	
Acute apical periodontitis (5224)	1478	1.91	6614	1.50	
Periapical abscess without sinus tract (5225)	683	0.88	2811	0.64	
Chronic apical periodontitis (5226)	6217	8.02	14,285	3.25	
Periapical abscess with sinus tract (5227)	725	0.94	2391	0.54	
Radicular cyst (5228)	62	0.08	280	0.06	
Others (5222, 5223, 5229)	412	0.53	1700	0.39	
Urbanization level					<.0001
1 (most urbanized)	30,098	38.84	146,716	33.36	
2	22,952	29.62	131,155	29.83	
3	12,395	16.00	73,143	16.63	
4 (average)	7834	10.11	57,336	13.04	
5	1067	1.38	6224	1.42	
6	1726	2.23	13,718	3.12	
7 (least urbanized)	1417	1.83	11,453	2.60	
Monthly income					<.0001
0	19,816	25.57	120,340	27.37	
1–15,840	9808	12.66	54,093	12.30	
15,481–25,000	22,079	28.49	142,544	32.42	
≥25,001	25,786	33.28	122,768	27.92	
Hospital level					<.0001
Medical center	5985	7.72	1063	0.24	
Regional hospital	4650	6.00	6175	1.40	
District hospital	1768	2.28	3152	0.72	
Local clinic	65,086	83.99	429,355	97.64	
Tooth scaling frequency per year after RCT					<.0001
≥1	15,059	19.43	69,800	15.87	
0–1	41,118	53.06	236,008	53.67	
0	21,312	27.50	133,937	30.46	
Diabetes mellitus					<.0001
Yes	4241	5.47	30,287	6.89	
No	73,248	94.53	409,458	93.11	
Hypertension					<.0001
Yes	9214	11.89	64,377	14.64	
No	68,275	88.11	375,368	85.36	
Coronary artery disease					<.0001
Yes	2540	3.28	16,605	3.78	
No	74,949	96.72	423,140	96.22	
Hyperlipidemia					<.0001
Yes	4990	6.44	31,935	7.26	
No	72,499	93.56	407,810	92.74	

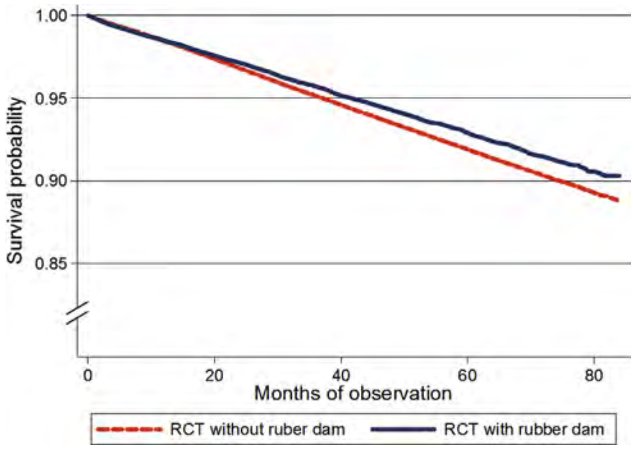

Figure 1. Cumulative survival probabilities for the teeth that received RCT between 2005 and 2011 segregated by rubber dam usage.

with the selection of irrigants from RCT (17), and rubber dam usage can reduce microorganism spread during dental procedures by 90%–98% (18). In summary, it is well-known that rubber dam usage provides advantages that are related to the reduction of the amount of bacteria inside the root canals and help to achieve more favorable outcomes of RCT.

However, there is a lack of direct evidence showing that the use of rubber dams improves the outcome of endodontic treatment, and the execution of controlled clinical trials to investigate this issue is not practical because of ethical concerns. In 1994, Van Nieuwenhuysen et al (19) evaluated the influence of a number of technical and clinical factors on the outcomes of 612 retreatment cases and showed that retreatment outcomes were significantly better for the cases that were isolated with rubber dams than for those that used cotton rolls. Nevertheless, this study used univariate statistics (Wilcoxon tests); thus, based on this study, the true relative risks of rubber dam usage for endodontic outcomes are unknown because of many factors (eg, the initial size of the periapical lesion and the occurrence of complications during retreatment) that might be associated with retreatment outcomes. Our study used multivariate Cox proportional hazards regression analyses and found that rubber dam usage significantly decreased the risk of tooth extraction (adjusted HR = 0.81; 95% CI, 0.79–0.84; Table 2); this finding provides positive evidence that might indirectly apply to endodontic outcomes.

Tooth extraction after RCT can result from many factors, including periodontal disease, dental caries, and tooth fractures (20). Vire (21) reported that only 8.6% of extractions resulted from true endodontic failure at a 1-year follow-up. Chen et al (10) reported that 10.7% of teeth were extracted because of endodontic problems in a 5-year follow-up period. Both of these studies indicate that endodontic failures only contribute to 8%–10% of tooth extractions. In contrast, tooth extraction is the first and major problematic event that follows RCT (59%–73.5%) according to several epidemiological studies (7–10). Although tooth extraction does not perfectly represent endodontic failures because endodontic failures only account for 10% of all tooth extractions, the use of the NHIRD provided us with a larger sample size, which enabled us to detect small differences.

The present study found that RCT performed in hospitals, including medical centers, regional hospitals, and district hospitals, exhibited a higher mean HR for extraction than those performed in local clinics (all $P < .0001$, Table 2). This result is similar to that of the study of Chen et al (22) in 2008 that found that tooth extraction rates after RCT are significantly greater in hospitals (10.0%) than in private clinics (7.7%, $P < .001$). Case severity, including factors such as tooth position, the curvature of the root canals, endodontic retreatment, and so on, might play an important factor in this difference because easier cases tend to be treated in local clinics rather than in hospitals, and the majority of difficult cases are referred to hospitals in Taiwan (22). To minimize the effect of different case severities, we excluded retreatment cases in the present study.

The present study has several limitations. One major limitation is that we could not identify the reasons behind the dentists' decisions to use rubber dams during RCT. According to Ahmad's review article in 2009, many dentist-related factors have been suggested to influence rubber dam usage, including postgraduate training, the treated tooth, the number of root canal fillings completed per month, the operator's

TABLE 2. Univariate and Multivariate Cox Proportional Hazards Analyses of Contributing Risk Factors, Including the Demographic Characteristics of the Patients, Rubber Dam Usage, Tooth Type, Hospital Level, Scaling Frequency, and Systemic Diseases, for Tooth Extraction after Root Canal Treatments

	Univariate			Multivariate		
Variables	Hazard ratio	95% CI	*P* value	Hazard ratio	95% CI	*P* value
Male vs female	1.22	1.19–1.25	<.0001	1.18	1.15–1.21	<.0001
Age						
21–40 vs ≤20	1.05	0.99–1.10	.11	1.04	0.99–1.10	.14
41–60 vs ≤20	1.79	1.70–1.89	<.0001	1.74	1.66–1.83	<.0001
>60 vs ≤20	2.32	2.20–2.45	<.0001	2.40	2.27–2.53	<.0001
Rubber dam use	0.89	0.86–0.92	<.0001	0.81	0.79–0.84	<.0001
Tooth type						
Premolar vs anterior	1.18	1.14–1.22	<.0001	1.24	1.19–1.28	<.0001
Molar vs anterior	1.90	1.84–1.96	<.0001	2.15	2.08–2.21	<.0001
Hospital Level						
Medical center vs local clinic	1.26	1.16–1.38	<.0001	1.37	1.25–1.51	<.0001
Regional hospital vs local clinic	1.27	1.18–1.37	<.0001	1.29	1.20–1.39	<.0001
District hospital vs local clinic	1.39	1.26–1.54	<.0001	1.34	1.21–1.48	<.0001
Scaling frequency per year after RCT						
≥1 vs 0	1.78	1.73–1.84	<.0001	1.80	1.75–1.86	<.0001
0–1 vs 0	2.09	2.00–2.17	<.0001	2.01	1.93–2.09	<.0001
Diabetes mellitus	1.64	1.57–1.70	<.0001	1.26	1.20–1.31	<.0001
Hypertension	1.51	1.47–1.56	<.0001	1.07	1.04–1.11	<.0001

Data are based on Taiwan's National Health Insurance Research Database from 2005–2011.

positive attitude and enhanced experience, and so on (4). Unfortunately, the NHIRD does not contain some clinical parameters related to the behavior of the dentists, such as the choice of irrigant, the techniques for cleaning and shaping, the root canal filling material, or 1 versus multiple treatments. The NHIRD also does not include data about the dentists' attitudes; thus, the cohort of dentists who routinely used rubber dams might give more attention to detail during RCT. Thus, rubber dam usage might be an intermediate variable that reflects the behaviors of the dentists or the quality of the dentists' endodontic work. However, the results of the present study show a real-world pattern that can provide dentists and patients with some valuable information.

Other limitations should also be considered. First, some dental treatments, such as post and core and prosthesis fabrication, are not covered by Taiwan's National Health Insurance program. Although full coverage of the tooth after RCT can prevent the treated tooth from experiencing fracture that would lead to extraction, the decision to use this procedure was made by the dentists and patients and was not associated with rubber dam usage. Furthermore, rubber dam usage during prefabricated post placement also results in higher success rates for root canal–treated teeth (23). Second, the study population was extracted from the NHIRD based on administrative claims data reported by dentists. Although we selected the criteria to improve the diagnostic accuracy, some important data were not reliable, such as the diagnoses of the teeth that received RCT. Third, although we excluded all retreatment cases that were indicated by specific treatment codes during RCT and those that were previously treated in 2001–2004, some of the cases might have received RCT before 2001. Lastly, some of the teeth were observed for relatively short times that were less than 1 year. However, after we removed these cases, a subsequent Cox regression analysis produced largely consistent results (inclusion period = 2005–2010; sample size = 447,435 teeth; mean observed time = 3.88 years; adjusted HR = 0.81; 95% CI, 0.78–0.84). These findings indicate that our results were not associated with observing time.

Conclusions

After adjusting for potential confounding factors, such as age, sex, tooth type, hospital level, tooth scaling frequency per year after RCT, and systemic diseases, including diabetes and hypertension, the adjusted tooth extraction HR of RCT with a rubber dam was 0.81 (95% CI, 0.79–0.84), which was significantly better than that associate with RCT without a rubber dam ($P < .0001$). The use of a rubber dam during RCT could provide a significantly higher survival rate after initial RCT. This result supports that rubber dam usage improves the outcomes of endodontic treatments.

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The authors deny any conflicts of interest related to this study.

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Rubber dam use less stressful for children and dentists

Abstracted from

Ammann P, Kolb A, Lussi A, Seemann R.

Influence of rubber dam on objective and subjective parameters of stress during dental treatment of children and adolescents - a randomized controlled clinical pilot study. *Int J Paediatr Dent.* 2012 Mar 8 [Epub ahead of print]

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Question: When placing fissure sealants does rubber dam compared with cotton wool rolls reduce stress and treatment times?

Design Randomised controlled trial, single centre and operator.

Intervention 72 patients (6-16 years) assessed as compliant, with no allergies, not on significant medication were divided into two groups by 'drawing sealed lots'. 234 fully erupted teeth were sealed. Molars and/or premolars were sealed dependant on age. Teeth were pre-cleaned with prophy paste. In the controls, teeth were isolated with buccal and lingual cotton rolls and salivary ejector in the intervention group a rubber dam was used. The same etching, rinsing and placement protocol was used in both arms.

Outcome measure Outcomes were: patients' subjective measures of pain using a visual analogue scale; blood pressure (before and after treatment), breath rate, pulse rate and skin resistance at five time points. The operator's pulse rate was measured and they completed a questionnaire on subjective mental and physical stress following treatment. Treatment times were recorded.

Results The breath rate was significantly ($P < 0.05$) lower and the skin resistance level was significantly higher during treatment with rubber dam compared to the control group. Subjective pain perception was significantly lower for the test group. The treatment time needed for the fissure sealing procedure was 12.4% less in the test group.

Conclusions The authors state; '... in the hands of an experienced dentist, isolation with rubber dam is less stressful for children and adolescents than isolation with cotton rolls, and can save valuable treatment time.' The operator's stress measures were lower with rubber dam and treatment time was reduced.

Commentary

Clinical dental research has, at last, started to include patient-centred outcomes, as well as the more usual clinician-centred outcomes, and this paper continues this trend. One of the reasons given for using rubber dam, alongside patient safety and improvement of treatment outcomes and field of vision, is to enhance patient comfort during treatment. The authors report that there is little evidence to support this, and that their study is the first to do so.

The study looked at the stress to operator and patient, of fissure sealant placement under rubber dam, compared with cotton roll isolation, and reported less stress for both with the rubber dam. Yet few dentists use rubber dam isolation for fissure sealant placement in their child patients, even for restorative work.[1] The 2009 Cochrane fissure sealant review[2] included only one study reporting using 'rubber dam if needed', and neither current BSPD[3] nor AAPD[4] guidelines on fissure sealing mention its use in their recommendations. One possible reason is that the optimal time to seal teeth in high caries-risk children is soon after eruption, when placement can be problematic.

So, should this study lead clinicians to start using rubber dam isolation for fissure sealing? As reported, the operator's 'personal preference for rubber dam is certainly a bias for the outcome of this study', giving doubt as to whether it can be considered a 'fair test'. Also, the conclusions don't seem to reflect the uncertainty in the results; although patients reported that subjective pain was lower for both sides of the mouth, none of their physiological outcomes reflected this. Pulse rate, skin resistance and blood pressure were not different between the rubber dam and cotton roll groups at any time points, and where there was a statistically significant difference on one side of the mouth, this was not found for the contralateral side. The only outcome measure in children consistently showing a statistically significant reduction for rubber dam over cotton rolls was their reports of subjective pain perception, but even this finding is complicated by the possibility that these were influenced by operator preferences.

What is most interesting about this paper is that from the operator's physiological measures and self-report he found cotton rolls more stressful to use and the children's results showed that they did not find either technique more stressful. Given the many advantages of rubber dam, this certainly merits consideration.

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Current Trends in Endodontic Treatment by General Dental Practitioners: Report of a United States National Survey

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Abstract

Introduction: In the United States almost 70% of root canal treatment (RCT) is performed by general dentists (GPs), yet little is known about their treatment protocols. **Methods:** A paper survey was mailed to 2000 United States GPs with questions about the types of endodontic cases treated, routine treatment protocols, use of newer technologies, and endodontic continuing education (CE). **Results:** Completed surveys were returned by 479 respondents (24%). GPs who perform RCT (84%) reported providing anterior (99%), bicuspid (95%), and molar (62%) RCT and retreatment (18%). Rubber dam was used always (60%), usually (16%), sometimes (13%), and never (11%). Newer technologies used by GPs included digital radiography (72%), magnification (80%), electronic apex locator (70%), and nickel-titanium rotary instrumentation (74%). Compared with GPs with >20 years of experience, those in practice for ≤10 years were more likely to use rubber dam ($P < .05$), nickel-titanium rotary instrumentation ($P < .001$), apex locators ($P < .001$), and magnification ($P < .01$); in contradistinction, GPs in practice >20 years were more likely to perform retreatments ($P < .05$). Women were less likely to perform retreatment or molar RCT (both $P < .05$). GPs with >5 hours of CE were more likely to use rotary instrumentation ($P < .001$), irrigant activation devices ($P < .01$), and apex locators ($P < .001$) and perform molar RCT ($P < .001$) and retreatment ($P < .05$), but no more likely to use rubber dam. **Conclusions:** Recent GP graduates (≤10 years) were more likely to adopt new technologies and use rubber dam than those who practiced for >20 years. More experienced GPs were more likely to take on complicated cases than those with fewer years of practice. There was no association between hours of CE and compliance with rubber dam usage. *(J Endod 2014;40:618–624)*

Key Words

American Dental Association, endodontic therapy, endodontics, general practice, magnification, microscope, radiography, root canal, surveys, technology

Developments in technology and materials continue to influence the practice of endodontics and have had a considerable impact on the way root canal treatment (RCT) is practiced by endodontists (1). Although information on various treatment practices by United States endodontists is available in the literature, very little is known about their general practitioner (GP) colleagues who were reported to perform 68% of RCTs in the United States in 2007 (2).

Endodontists in the United States have been surveyed on armamentarium (1), irrigation regimens (3), intraosseous anesthesia (4), nickel-titanium (NiTi) rotary instrumentation (5), magnification (6), and one-appointment endodontics (7). Some of this information has been gathered in surveys of GPs practicing in other countries (8–13). For example, in Australia, only 22% of GPs were reported to use NiTi rotary instrumentation in 2004 (12), whereas in 2003, 75% of GPs used sodium hypochlorite, with more than 90% using 1% concentration (10). In the United Kingdom, rubber dam was always or frequently used by less than 20% of dentists who provided endodontic treatment under the National Health Service; among those who used rubber dam, 71% reported using sodium hypochlorite versus only 38% of those not using a rubber dam (13). Surveys of GPs practicing in Hong Kong and Denmark have shown that the majority perform RCTs over more than 1 visit (8, 14).

The purpose of this study was to collect information about the techniques and armamentarium currently used by GPs in the United States who perform endodontic treatment, with the intention of identifying areas where more recently developed techniques, technologies, or equipment are being used.

Materials and Methods

A questionnaire was designed on the basis of previously published surveys of endodontists and GPs (4, 6, 9, 13) (Fig. 1). The study received formal review and waiver from the appropriate institutional review board.

A pilot questionnaire was circulated to a group of GPs (n = 20) in Portland, OR. Eighty-five percent reported providing endodontic treatment, and this percentage was used to calculate the sample size for the current study. The estimated sample size with 95% significance and 5% type II error was 197. However, to compensate for nonresponse, the survey was sent to 2000 active members of the American Dental Association (ADA) practicing general dentistry throughout all 50 states. A list of mailing addresses of 2000 randomly selected GPs was purchased from the ADA via a third party, Hippo Direct (Cleveland, OH).

All survey participants were asked to provide demographic information on gender, years in practice, and geographic region of practice. Other questions addressed the types of cases treated, routine treatment protocols, use of newer technologies, and hours of endodontic continuing education (CE) taken in the last 5 years. All responses were anonymous. A postage-paid return envelope was provided. The survey was mailed

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The majority of endodontic treatment in the U.S. is performed by general dentists. While considerable information is available in the literature concerning the practice of endodontics by specialists, little is reported for general practitioners. Therefore, the aim of this study is to collect information about the techniques and materials currently utilized by general practitioners performing endodontic treatment. We hope to illuminate areas where more recently developed techniques, technologies, or materials are being utilized or possibly under-utilized.

Your participation in this brief survey would be of great value. Even if you do not perform endodontic treatment in your practice, your response to questions 1, 18, 19, 20 and 21 would be very helpful. The survey takes a few minutes to complete and you may return it via postage-paid mail. Please select the answers that most closely represent your routine practice as it pertains to endodontics.

Thank you for your time and assistance. We think this information will be interesting and helpful to the profession.

Questionnaire

1. **Do you perform endodontic treatment in your practice?**
   ___Yes ___ No If No, please skip to question 18.

2. **On average, how many endodontic cases do you treat in your office per month?**
   ___ 1-5 ___ 6-10 ___ 11-15 ___ 16-20 ___ >20

3. **Which types of cases do you routinely treat? (Check all that apply)**
   ___ Anterior ___ Bicuspid ___ Molar ___ Retreatment

4. **Of the following supplemental anesthesia techniques, indicate any you use routinely. (Check all that apply)**
   ___ Stabident ___ X-Tip ___ Intrapulpal ___ PDL injection
   ___ Trans-septal injection ___ Mandibular infiltration with 4% articaine

5. **How often do you use rubber dam isolation?**
   ___ Always ___ Usually ___ Sometimes ___ Never

6. **Do you use magnification?**
   ___ No ___ Loupes ___ Microscope ___ Other

7. **How do you determine working length?**
   ___ Radiographs alone ___ Electronic Apex Locator alone
   ___ Electronic Apex Locator with radiographic confirmation

8. **Do you use digital radiography?** ___ Yes ___ No

9. **What instruments do you routinely use? (Check all that apply)**
   ___ SS K-files ___ C-files ___ Hedstrom files ___ NiTi Hand files
   ___ Gates Glidden ___ Peeso Reamers ___ NiTi Rotary files

(Continued on back)

Figure 1. (*A* and *B*) Survey questionnaire.

once, participants were not compensated for responding, and no follow-up contact was made.

Statistical Methods

Data analysis was conducted by using SPSS (Statistics 20; IBM Corporation, Armonk, IL). First, the distribution of GPs performing endodontic treatment by gender, years of practice, ADA region, and endodontic-related CE was examined. The rest of the analysis was conducted for only those respondents who reported performing endodontic treatment and reported as a percentage of those who performed endodontic treatment. The χ^2 test was used to assess the binary relationship between endodontic-related CE with each of treatment of molars, endodontic retreatment, use of rubber dam, and use of adjunctive irrigant activation device. A series of logistic regression models were constructed to assess the factors associated with routine endodontic treatment (use of rubber dam), more complicated treatment (molar RCT, retreatment), and the use of newer technologies (magnification, NiTi rotary instrumentation, adjunctive irrigant activation devices, apex locator). All models were adjusted for gender, hours of endodontic-related CE, and years in practice.

Results

Characteristics of GPs Who Participated in the Study

Of the 2000 surveys sent to GPs, 479 completed surveys were returned for a 24% response rate. Because of the relatively low response

B

10. Do you routinely use a paste/gel type chelator/lubricant during canal instrumentation?

___ Yes ___ No

11. Do you use sodium hypochlorite as your primary irrigant?

___ Yes ___ No

12. Do you use any type of adjunctive activation device during irrigation? (Sonics, Ultrasonics, Endo Activator™, Endo Vac™)

___ Yes ___ No

13. Do you remove the smear layer?

___ Yes ___ No

14. Do you routinely treat your endodontic cases in single or multiple visits?

___ Single visit ___ Multiple visits ___ No preference

15. If multiple visits, do you use an intracanal medicament between appointments?

___ Yes ___ No

16. Do you leave teeth open for drainage?

___ Yes ___ No

17. What obturation technique do you most commonly use?

___ Cold Lateral compaction ___ Warm lateral compaction
___ Continuous Wave compaction ___ Paste Filling
___ Carrier-Based Obturator ___ Silver Point
___ Thermomechanical compaction
___ Schilder technique (Classic Warm Vertical compaction)

18. About how many hours of endodontic CE have you taken in the last five years?

___ None ___ 1-5 ___ 6-10 ___ 11-15 ___ 16-20 ___ >20

19. Gender: ___ Male ___ Female

20. How many years have you been in practice?

___ 1-5 ___ 6-10 ___ 11-15 ___ 16-20 ___ >20

21. In what ADA region of the country do you practice?

___ Northeast (MA, RI, CT, VT, NH, ME, NY, NJ)
___ Mid Atlantic (PA, MD, DE, WV, VA, NC, SC, DC)
___ Southeast (KY, TN, AR, LA, MS, AL, GA, FL)
___ Great Lakes (MN, WI, IL, IN, MI, OH)
___ Mid West (NM, CO, WY, MT, ND, SD, NE, KS, OK, TX, IA, MO)
___ Western (WA, OR, CA, ID, NV, UT, AZ, AK, HI)

Thank you for your participation.

Figure 1. (*continued*).

rate to the survey, we calculated the sample error by using the actual number of respondents and highest possible variation (50%). The highest possible sample error in this study was 4.4%. Table 1 shows the characteristics of the respondents. Eighty-four percent of respondents reported providing RCT; of these, 56% had >20 years of clinical experience. The sample of respondents was fairly evenly distributed geographically, with a slight underrepresentation in the Mid Atlantic region. The male-to-female ratio was consistent with current ADA membership based on the 2009 Distribution of Dentists data (15). One to 10 hours of CE were obtained by 53% of respondents in the last 5 years.

Routine Endodontic Practice by GPs in the United States

The majority of respondents (58%) treated 1–5 cases per month (Table 2). GPs reported treating predominantly anterior (99%) and bicuspid (95%) teeth and also provided molar RCT (62%) and retreatment (18%). The majority of respondents preferred to complete treatment in a single visit (63%). There was a trend for GPs who had a greater number of CE hours to provide molar endodontic treatment and endodontic retreatment (χ^2, $P < .01$ and $P < .001$, respectively) (Fig. 2).

Eleven percent of respondents reported never using a rubber dam. Only 60% of respondents always use a rubber dam during RCT. A higher percentage of women use a rubber dam than men (65.3% and 57.7%, respectively); however, this difference was not statistically significant. Similarly, there was no significant association between rubber dam usage and hours of CE (Fig. 3). Sodium hypochlorite (NaOCl) was the primary root canal irrigant used by 93% of GPs. The majority reported use of a paste/gel-type chelator/lubricant during instrumentation and smear layer removal (83% and 73%, respectively). Cold lateral compaction was the most common obturation technique (40%), with various

TABLE 1. Characteristics of GPs Who Participated in the Study (n = 479)

	Overall (%)	Endodontic "yes" (%)	Endodontic "no" (%)	P value
Perform endodontic treatment				
Yes	84			
No	16			
Gender				
Male	74	76	24	<.05
Female	26	62	38	
Years in practice				
1–5	13	92	8	
6–10	11	90	10	.06
11–15	11	91	9	
16–20	9	77	23	
>20	56	81	19	
ADA region of the country where practice				
Northeastern	16	85	15	
Southeast	14	87	13	.9
Mid West	19	82	18	
Mid Atlantic	9	84	16	
Great Lakes	20	85	15	
Western	22	83	17	
Hours of endodontic CE last 5 years				
None	14	53	47	
1–5	29	81	19	
6–10	24	92	8	
11–15	11	96	4	.001
16–20	10	98	2	
>20	12	93	7	

warm gutta-percha techniques used by an additional 54%. No respondent reported use of silver points. One-third of respondents (34%) reported leaving teeth open for drainage.

Newer Technologies Used by GPs

Table 3 shows information on use of newer technologies during endodontic treatment. GPs routinely used some form of magnification, typically loupes (75%), as well as a variety of supplemental anesthesia techniques. The majority reported using an electronic apex locator (70%) to determine working length either alone (18%) or combined with radiographic confirmation (52%). Digital radiography was used by 72% of study participants. Root canal instrumentation with NiTi rotary files was reported by 74% of respondents. Adjunctive activation of root canal irrigants by using devices incorporating negative pressure (EndoVac; SybronEndo, Orange, CA) or sonic, subsonic (EndoActivator; DENTSPLY International, York, PA), or ultrasonic energy was used by 19% of participants. The use of adjunctive irrigation devices was significantly associated with increased hours of CE (P < .001), with those who reported more hours of CE more likely to use adjunctive irrigation (Fig. 3).

Regression Analyses

Table 4 reports the odds ratios (ORs) with 95% confidence intervals for the probabilities of performing standard endodontic procedures and use of advanced techniques. Female dentists had higher odds of using rubber dam than male dentists, but the difference was not statistically significant. GPs with >5 hours of CE were more likely to perform molar endodontic treatment (OR, 2.56; P < .001) and retreatment (OR, 2.00; P < .05) or use NiTi rotary instruments (OR, 2.29; P < .001), irrigant activation devices (OR, 2.39; P < .01), and apex locators (OR, 2.30; P < .001). Compared with GPs with more than 20 years of experience, those in practice for 10 years or less were more likely to use rubber dam (OR, 1.92; P < .05), rotary instruments

TABLE 2. Routine Endodontic Practice by GPs in the United States

Types of cases routinely treated (all that apply)	%
Anterior	99
Bicuspid	95
Molar	62
Retreatment	18
Average number of endodontic cases treated per month	
1–5	58
6–10	29
11–15	8
16–20	3
>20	2
Prefer to treat endodontic cases in single or multiple visits	
Single visit	63
Multiple visits	21
No preference	16
Rubber dam isolation	
Always	60
Usually	16
Sometimes	13
Never	11
Use of a paste/gel-type chelator/lubricant during canal instrumentation	
Yes	83
No	17
Sodium hypochlorite as primary irrigant	
Yes	93
No	7
Removal of smear layer	
Yes	73
No	27
Use of intracanal medicament between appointments for multiple-visit cases	
Yes	78
No	22
Leave teeth open for drainage	
Yes	34
No	66
Obturation technique most commonly used	
Cold lateral compaction	40
Carrier-based obturator	19
Warm lateral compaction	12
Schilder technique (classic warm vertical compaction)	9
Thermomechanical compaction	8
Continuous wave compaction	6
Paste filling	3
Other	3
Silver point	0

(OR, 4.38; P < .001), apex locators (OR, 3.41; P < .001), and magnification (OR, 2.75; P < .01); in contradistinction, GPs with >20 years of experience were more likely to provide retreatment than those with fewer years of practice (OR, 0.33; P < .05). Female GPs were less likely to provide retreatment or molar endodontic treatments than male GPs (OR, 0.29 and OR, 0.55, respectively; both P < .05).

Discussion

It is likely that the percentage of GPs who report performing endodontic treatment is overestimated in our results, because those who did not respond are more likely to be the ones who do not perform RCT. Previous surveys of endodontists practicing in the United States reported that newer technologies have been widely adopted (1, 3–6). To the authors' knowledge, this is the first published report regarding use of such technologies by United States GPs in the 21st century. Although the basic purpose of this study was to provide general, baseline information about GPs, some comparisons to endodontists can be made. For example, 72% of GPs reported using digital radiography, which corresponds to 73% of board-certified endodontists (1).

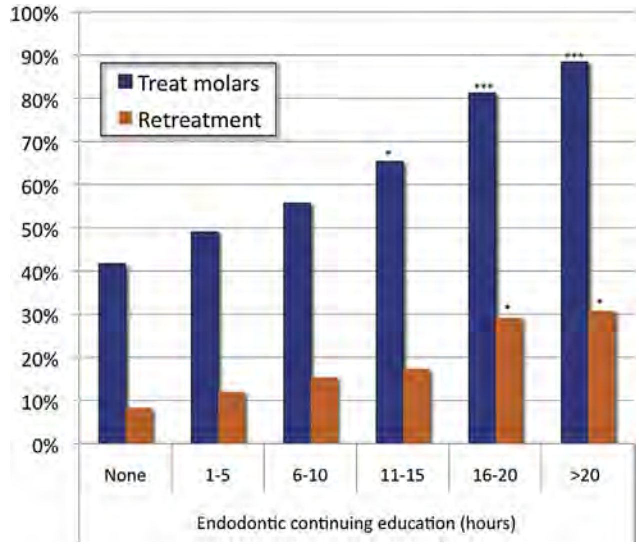

Figure 2. Percentages of those GP respondents who perform endodontic treatment who treat molar or retreatment cases by hours of endodontic CE. Significant differences to not treated: ***P < .001, *P < .05.

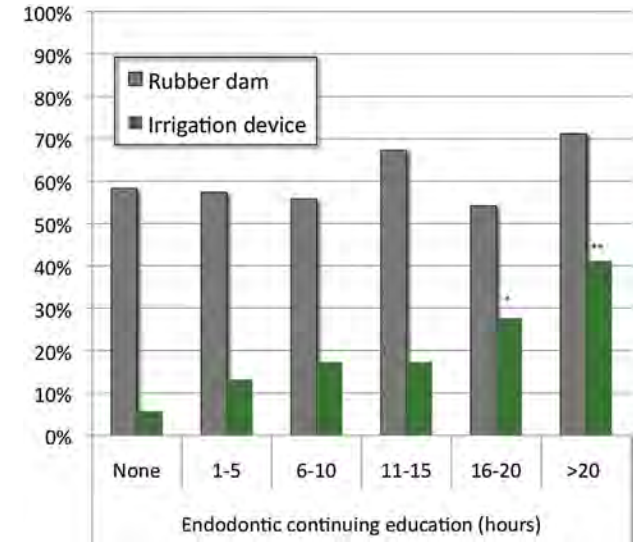

Figure 3. Percentages of those GP respondents who perform endodontic treatment who always use rubber dam or use adjunctive irrigation device by hours of endodontic CE. Significant differences to non-usage: **P < .01, *P < .05.

Most respondents (56%) reported more than 20 years in practice (Table 1), suggesting the predominant age group in this survey was older than 45 years. This appears to correspond with the age distribution of GPs in the United States according to a 2009 ADA report that 65% of active private practitioners are older than 45 years (15). Routine use of NiTi rotary files was reported by the majority of this group of experienced clinicians (66%). These findings are of interest because it is unlikely that these GPs were taught NiTi rotary file techniques at dental school. NiTi rotary files were first described in 1988 (16) and did not become widely used until the mid-1990s. The usage of NiTi rotary files may contribute to more favorable outcomes in endodontic treatment (17). In this study, 74% of GPs reported routine use of NiTi rotary instrumentation (Table 3), compared with 98% of endodontists (5). In contrast to practices in other countries (8, 9), GPs in the United States prefer to provide endodontic treatment in a single visit (63%) (Table 2); this may reflect the reported advantage of NiTi rotary instrumentation to shorten treatment time (18).

Perhaps the most clinically significant finding in this article is the lack of compliance with the standard of care regarding rubber dam isolation for nonsurgical RCT in the United States. This is similar to other countries (9, 11, 13), despite evidence that endodontic outcomes are more favorable when rubber dam isolation is used (19). The American Association of Endodontists Position Statement specifies that rubber dam usage is the standard of care (20). However, 11% of GPs reported never using a rubber dam, and only 60% of respondents reported always using a rubber dam when providing endodontic treatment (Table 2). The latter number is essentially unchanged from a 1996 report that 59% of GPs always used a rubber dam during RCT in contrast to 94% of endodontists (21). Similarly, a recent survey conducted in the United States showed that 15% of GPs participating in a dental practice research network never used a rubber dam during RCT, and only 44% always use a rubber dam, compared with 100% of endodontists (22). Also interesting is the lack of any statistically significant association with hours of endodontic CE. Because of the other results in the regression analysis, one might suppose that GPs who attended more hours of CE would be more likely to follow this important standard of care.

Root canal irrigation is an extremely important component of nonsurgical endodontic treatment because more than 35% of the root canal surface can be left uninstrumented, even with the use of NiTi rotary instrumentation (23). In this study the overwhelming majority of GPs (93%) reported using NaOCl as their primary irrigant (Table 2), which is consistent with usage among United States endodontists (91%) (5). The major advantages of NaOCl are tissue dissolution (24) and antimicrobial activity (25). Another recent survey of endodontists in the United States reported that 57% used NaOCl as their primary irrigant in concentrations greater than 5% (3). The present survey did not ask about the concentration of NaOCl used by GPs, but this could be investigated in a future study. Recent studies have highlighted the potential benefits of activation of irrigants during endodontic treatment to aid in dentin debris removal from apical irregularities *in vitro* (26) and reduction of bacterial counts (27). In this study only 19% of GPs reported using an irrigation adjunct, compared with at least half of endodontists as reported elsewhere (3). This was significantly associated with CE attendance (Fig. 3), suggesting that this might be an important area of focus for future endodontic CE courses.

Reports published in the 1990s have indicated that most United States dental schools (>90%) taught only cold lateral compaction in their pre-doctoral programs (28). On the basis of years of practice, it is likely that the majority of this study's population graduated before the mid-1990s and were thus taught cold lateral compaction in dental school. In this study, 40% of GPs reported using cold lateral compaction, and 54% used various warm obturation techniques (Table 2). There are few data on the influence of obturation technique on treatment outcomes. A meta-analysis reported that a higher rate of overextension was associated with warm gutta-percha obturation compared with cold lateral compaction, but that other factors such as postoperative pain prevalence, long-term outcomes, and obturation quality were no different (29). However, these data suggest that a significant number of GPs have changed their obturation technique from cold lateral to some form of warm gutta-percha compaction. This could possibly be related to information learned in CE courses, but because of the number of different warm gutta-percha techniques reported, a meaningful correlation with CE attended could not be made in the present study. It should also be recognized that the GPs who responded to our survey may be the ones who have received strong undergraduate training in endodontics and are more comfortable accommodating newer

TABLE 3. Newer Technologies Used by GPs in the United States

Supplemental anesthesia techniques used routinely (all that apply)	%
Intrapulpal	64
PDL	64
Mandibular infiltration with 4% articaine	54
X-tip	8
Transseptal injection	7
Stabident	6
Use of magnification	
Loupes	75
Microscope	2
Other	3
None	20
Determination of working length	
Electronic apex locator alone	18
Radiographs alone	30
Electronic apex locator with radiographic confirmation	52
Digital radiography	
Yes	72
No	28
Root canal instruments routinely used (all that apply)	
NiTi rotary files	74
Stainless steel files	68
Gates Glidden files	46
NiTi hand files	29
Hedstrom files	22
Peeso reamers	11
C-files	9
Adjunctive activation device during irrigation	
Yes	19
No	81

techniques without formal CE training. Interestingly, although 19% of GPs used carrier-based obturation, only 6.5% of endodontists have reported doing the same (1). This could be attributed to carrier-based obturation presenting challenges to removal during retreatment (30).

A recent prospective randomized trial demonstrated a statistically significant improvement in anesthesia success with the use of intraosseous anesthesia, compared with a periodontal ligament (PDL) injection or repeating the inferior alveolar block injection (31). In this study population only 15% of GPs reported using the X-tip (X-tip Technologies, Lakewood, NJ) or Stabident (Fairfax Dental, Miami, FL) intraosseous systems, compared with 43% of endodontists as previously reported (4). In contrast, more GPs used PDL injections (64%), compared with endodontists (50%) (Table 3). The intrapulpal injection is often considered a technique of last resort because it is commonly quite painful, yet 64% of GPs reported routine use of this injection as a supplemental anesthesia technique. On the other hand, a recent clinical study showed a statistically significant increase in anesthesia success when the inferior alveolar nerve block was supplemented with a buccal infiltration of 4% articaine (32), and the use of this supplemental anesthesia technique was reported by 54% of GP respondents (Table 3).

A clinical study showed that only 17.2% of second mesiobuccal canals were located without the aid of magnification, with 3 times more likely chance to locate the second mesiobuccal canal with the use of some form of magnification (33). The use of the dental operating microscope (DOM) by endodontists was reported in 1999 to be 52% (34), but it had dramatically increased to 90% by 2007, with usage even higher (95%) among newer graduates (6). In the present study, magnification was reported to be widely used (80% of respondents), predominantly in the form of loupes (75%) (Table 3). Only 2% of GPs reported using a DOM, which is perhaps not surprising because the cost of a microscope is quite high. With such a small number of GPs reporting use of the DOM, no meaningful correlations with years in practice, types of cases treated, or CE attendance could be made.

In conclusion, this survey found that the majority of the 84% of GP respondents in the United States who perform endodontic treatment have widely adopted newer technologies such as digital radiography, magnification, electronic apex locators, and NiTi rotary instrumentation as part of their endodontic practice. More recent graduates (≤10 years) were more likely to adopt new technologies and adhere to the rubber dam standard of care than those who practiced for >20 years. At the same time, more experienced dentists had more confidence to take on more complicated cases (retreatment, molars) than those with fewer years of practice. CE appears to be beneficial to adopting new technologies but is less effective in influencing standards of practice, as demonstrated by the low compliance with the standard of care with regard to rubber dam usage. This may be because many CE courses for GPs are sponsored by dental manufacturers who have a product to sell and thus are geared toward educating the participants about the company's particular product(s). It should be noted that although this study revealed some important information about the patterns of endodontic practice by GPs, particularly in relation to the use of rubber dam and adopting new technologies, the findings cannot be generalized to GPs in the entire United States because of the limitations of a relatively small sample and 24% response rate to the survey. An additional limitation is variation in the geographic and gender distribution of our sample. In comparison with demographic data from the ADA (15), our survey had a higher percentage of women (26% versus 21%) and relatively higher and lower response rates from the New England and Mid Atlantic regions, respectively, relative to the actual geographic distribution of dentists there. However, these differences were not statistically

TABLE 4. ORs (95% Confidence Intervals) Adjusted for Gender, Hours of CE, and Years in Practice for the Probabilities of GPs in the United States Performing Endodontic Procedures and Using Newer Technology

	Gender		CE		Years in practice		
Procedure	Male	Female	≤5 h	>5 h	>20	11–20	1–10
Use rubber dam	1	1.21 (0.73–2.01)	1	1.30 (0.85–2.00)	1	1.26 (0.74–2.13)	1.92* (1.14–3.26)
Treat molars	1	0.55* (0.34–0.91)	1	2.56† (1.66–3.96)	1	0.83 (0.49–1.42)	1.31 (0.77–2.24)
Retreatment	1	0.29* (0.11–0.75)	1	2.00* (1.06–3.75)	1	0.55 (0.27–1.13)	0.33* (0.14–0.78)
Use magnification	1	0.68 (0.38–1.23)	1	1.25 (0.75–2.08)	1	1.69 (0.88–3.25)	2.75‡ (1.38–5.49)
Use NiTi rotary	1	0.67 (0.38–1.20)	1	2.29‡ (1.41–3.72)	1	1.98* (1.06–3.69)	4.38† (2.19–8.77)
Use irrigant activation	1	0.77 (0.39–1.50)	1	2.39‡ (1.31–4.37)	1	0.69 (0.34–1.38)	0.89 (0.47–1.71)
Use apex locator	1	0.80 (0.46–1.39)	1	2.30† (1.44–3.66)	1	1.64 (0.91–2.94)	3.41† (1.81–6.40)

*$P < .05$.
†$P < .001$.
‡$P < .01$.

significant. In addition, the calculated sample error of 4.4% does not generally change the conclusions of the article.

It is hoped that this baseline information providing a snapshot of current endodontic practice by United States GPs can serve as a launching point for further, more in-depth investigations of particular topics of interest and identify potential areas of focus in the development of CE programs.

Acknowledgments

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The authors deny any conflicts of interest related to this study.

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Rubber dam isolation for restorative treatment in dental patients (Review)

Wang Y, Li C, Yuan H, Wong MCM, Zou J, Shi Z, Zhou X

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[Intervention Review]

Rubber dam isolation for restorative treatment in dental patients

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ABSTRACT

Background

Successful restorations in dental patients depend largely on the effective control of moisture and microbes during the procedure. The rubber dam technique has been one of the most widely used isolation methods in dental restorative treatments. The evidence on the effects of rubber dam usage on the longevity of dental restorations is conflicting. Therefore, it is important to summarise the available evidence to determine the effects of this method.

Objectives

To assess the effects of rubber dam isolation compared with other types of isolation used for direct and indirect restorative treatments in dental patients.

Search methods

We searched the following electronic databases: Cochrane Oral Health's Trials Register (searched 17 August 2016), Cochrane Central Register of Controlled Trials (CENTRAL; 2016, Issue 7) in the Cochrane Library (searched 17 August 2016), MEDLINE Ovid (1946 to 17 August 2016), Embase Ovid (1980 to 17 August 2016), LILACS BIREME Virtual Health Library (Latin American and Caribbean Health Science Information database; 1982 to 17 August 2016), SciELO BIREME Virtual Health Library (1998 to 17 August 2016), Chinese BioMedical Literature Database (CBM, in Chinese) (1978 to 30 August 2016), VIP (in Chinese) (1989 to 30 August 2016), and China National Knowledge Infrastructure (CNKI, in Chinese) (1994 to 30 August 2016). We searched ClinicalTrials.gov and the World Health Organization International Clinical Trials Registry Platform, OpenGrey and Sciencepaper Online (in Chinese) for ongoing trials. There were no restrictions on the language or date of publication when searching the electronic databases.

Selection criteria

We included randomised controlled trials (including split-mouth trials) assessing the effects of rubber dam isolation for restorative treatments in dental patients.

Data collection and analysis

Two review authors independently screened the results of the electronic searches, extracted data and assessed the risk of bias of the included studies. We resolved disagreement by discussion.

Main results

We included four studies that analysed 1270 participants (among which 233 participants were lost to follow-up). All the included studies were at high risk of bias. We excluded one trial from the analysis due to inconsistencies in the presented data.

The results indicated that dental restorations had a significantly higher survival rate in the rubber dam isolation group compared to the cotton roll isolation group at six months in participants receiving composite restorative treatment of non-carious cervical lesions (risk ratio (RR) 1.19, 95% confidence interval (CI) 1.04 to 1.37, very low-quality evidence). It also showed that the rubber dam group had a lower risk of failure at two years in children undergoing proximal atraumatic restorative treatment in primary molars (hazard ratio (HR) 0.80, 95% CI 0.66 to 0.97, very low-quality evidence). One trial reported limited data showing that rubber dam usage during fissure sealing might shorten the treatment time. None of the included studies mentioned adverse effects or reported the direct cost of the treatment, or the level of patient acceptance/satisfaction. There was also no evidence evaluating the effects of rubber dam usage on the quality of the restorations.

Authors' conclusions

We found some very low-quality evidence, from single studies, suggesting that rubber dam usage in dental direct restorative treatments may lead to a lower failure rate of the restorations, compared with the failure rate for cotton roll usage. Further high quality research evaluating the effects of rubber dam usage on different types of restorative treatments is required.

PLAIN LANGUAGE SUMMARY

Does isolating the site of a dental restoration during treatment improve the performance of the restoration?

Review question

This review examined whether different isolation methods affect the performance of dental restorations.

Background

Restorative dental treatments are used to repair damage to teeth caused by tooth decay or accidents. Creating a physical barrier around a treatment site to reduce contamination of the site with saliva is a common practice. Reducing the amount of saliva in the area may enable the materials used for repair to bond together more effectively, improving the performance and reliability of the restoration. It may also reduce exposure to bacteria in the mouth.

Two methods of creating a barrier are commonly used; either a rubber dam around the tooth or cotton rolls together with suction to remove excess saliva. The rubber dam method involves using a sheet of latex in a frame. A small hole is made in the sheet and it is placed over the tooth to be treated creating a barrier around it. Using a rubber dam can isolate the tooth from the rest of the person's mouth, which allows the tooth to be repaired dry and with relatively less exposure to bacteria in the mouth. A common alternative method of isolation of the tooth is the use of cotton rolls combined with the removal of excess saliva by suction. The evidence on the effects of rubber dam usage versus cotton roll usage is conflicting.

Study characteristics

The evidence in this review, which was carried out together with Cochrane Oral Health, is up-to-date as of 17 August 2016. We included four studies that evaluated 1037 participants, mostly children, who were undergoing different types of dental restorative treatments, using materials which require effective moisture control to reduce failure rates. For example, fissure sealing, resin or composite fillings at the gum margin, and proximal atraumatic restorative treatment in primary molars. All of the included studies compared the use of rubber dam and cotton rolls as two different isolation methods.

Key results

There is some evidence to suggest that the use of a rubber dam may increase the survival time of dental restorations compared to the use of cotton rolls as an isolation method.

The studies did not include possible side effects.

Quality of the evidence

The evidence presented is of very low quality due to the small amount of available studies, uncertain results and problems related to the way in which the available studies were conducted.

SUMMARY OF FINDINGS FOR THE MAIN COMPARISON *[Explanation]*

Rubber dam versus cotton rolls for restorative treatment in dental patients

Patient or population: dental patients
Settings: China and Kenya
Intervention: rubber dam versus cotton rolls

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Cotton rolls	Rubber dam				
Survival rate (6 months) assessed clinically and radiographically Follow-up: mean 6 months	**765 per 1000**	**910 per 1000** (796 to 1000)	**RR 1.19** (1.04 to 1.37)	162 (1 study)	⊕○○○ **very low**[1]	There was weak evidence showing that the use of rubber dam might result in higher survival rate of the restorations compared to cotton rolls at 6 months' follow-up Weak evidence also indicating the usage of rubber dam might relatively increase the survival rate of restorations after 24 months' follow-up compared to cotton rolls (HR 0.80, 95% CI 0.66 to 0.97; 559 participants; 1 study; very low-quality evidence)

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI)
CI: confidence interval; **HR:** hazard ratio; **RR:** risk ratio

GRADE Working Group grades of evidence
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.

[1] Downgraded 3 times due to being a single study, at high risk of bias and for indirectness: the included study had high risk of bias and was only conducted in China or Kenya population that may not be applicable in other populations.

BACKGROUND

Description of the condition

Restorative dental treatments are used to repair damage to teeth caused by caries or trauma. Direct restorative dental treatments (commonly known as 'fillings') repair damage to the visible tooth, such as restorations using either amalgam or a resin composite material. Indirect restorations are prepared outside the person's mouth, using a dental impression from the prepared tooth. Examples of indirect restorations include inlays, onlays, crowns, bridges and veneers.

Successful restorations depend on a number of factors, but perhaps the most important ones are moisture and microbe control. Excluding moisture and saliva from the tooth or root being restored facilitates the bonding of the restorative material to the tooth and decreases the risk of infection or re-infection. Poor bonding or secondary caries may compromise the success or longevity of the restoration, or both.

Description of the intervention

A common method of isolation and moisture control in restorative dentistry is the use of cotton rolls combined with aspiration by saliva ejector. This technique is widely available and low cost, but has the disadvantage that the dentist is required to replace sodden cotton rolls frequently during the treatment to keep the operative field dry.

An alternative method of isolation of the tooth undergoing restorative treatment is a rubber dam, an isolation method, introduced to the dental profession by Dr Sanford C Barnum on 15 March 1864 (Elderton 1971a; Elderton 1971b; Elderton 1971c). Since then, many researchers have improved its application and it is now a frequently used, practical alternative to cotton balls (Bhuva 2008; Carrotte 2000; Carrotte 2004; Reuter 1983). A rubber dam is usually a small sheet of latex (though non-latex versions are available) placed in a frame. A small hole is made in the sheet and placed over the tooth to be treated. The rubber dam is held on to the tooth being restored by means of a small clamp. This isolates the tooth from the rest of the person's mouth, which keeps the tooth to be restored dry and relatively less exposed to intraoral bacteria.

Potential advantages of the use of a rubber dam include superior isolation of the tooth to be treated from the saliva in the mouth (Cochran 1989), providing the dentist with improved visibility, reduced mirror fogging, enhanced visual contrast, soft tissue retraction (Reid 1991), protection of the person by preventing ingestion or aspiration of instruments (Susini 2007; Tiwana 2004), materials, or irrigant (Cohen 1987), and preventing oral soft tissues from contact with irritating or harmful materials used during operative procedures, such as phosphoric acids or sodium hypochlorite (Lynch 2003). There is also a reduction in the risk of cross-infection in the dental practice by decreasing the microbial content of splatters and air turbine aerosols produced during dental treatment (Harrel 2004).

However, there are real and perceived negative effects to the use of rubber dams. Most often cited are concerns over patient acceptance, time needed for application, cost of materials and equipment, insufficient training and inconvenience (Hill 2008; Koshy 2002; Stewardson 2002). Latex allergy, rubber dam clamp fracture (Sutton 1996), and damage to the mucosa when placing or removing the rubber dam, in rare cases, may also impede the wide use of rubber dam.

A number of modifications of rubber dam techniques have been described. John Mamoun suggested the use of a rubber dam with a custom prosthesis to achieve dry-field isolation of the distal molars with short clinical crowns (Mamoun 2002). Also, the slit rubber dam technique used when preparing teeth for indirect restoration could promote operating efficiency (Perrine 2005). Further developments in rubber dam technique are ongoing.

How the intervention might work

Creating a physical barrier around a treatment site to reduce contamination due to moisture and microbes is common practice in medical and dental procedures. Isolating the tooth to be restored from the contamination of moisture or saliva in restoration placement may promote the bonding of the restorative materials to the tooth, while rubber dam usage is mandatory for endodontics for reasons of safety and cross infection control. The use of a rubber dam in restorative dentistry has the added advantage of providing the dentist with a broader work surface which also traps small pieces of debris and treatment solutions protecting the person from inadvertently swallowing these. When rubber dams are used in association with amalgam restorations, they may reduce the person's exposure to potentially harmful adverse effects of mercury ingestion (Halbach 2008; Kremers 1999).

Why it is important to do this review

Both rubber dam and cotton rolls are currently used in dentistry to isolate the treatment field and to exclude moisture. There are advantages and disadvantages associated with each method from the different points of view of person and dentist. Moreover, several randomised controlled trials have been conducted to determine whether the use of a rubber dam for restorative treatments influences the treatment outcomes (Carvalho 2010; Kemoli 2010; Ma 2012). However, the results from these trials appear to be conflicting. The purpose of this systematic review is to evaluate the effectiveness of the rubber dam as an isolation and moisture reduction technique used in restorative dentistry, together with any adverse or negative effects. This information will then be available so that both dentists and their patients can make informed decisions about the benefits and possible negative effects of different isolation and moisture control techniques to be used for specific dental restorations.

OBJECTIVES

To assess the effects of rubber dam isolation compared with other types of isolation used for direct and indirect restorative treatments in dental patients.

METHODS

Criteria for considering studies for this review

Types of studies

All randomised controlled trials or quasi-randomised controlled trials (including split-mouth/cross-over studies).

Types of participants

People undergoing any type of direct or indirect restorative treatment. There were no restrictions of age or gender.
Restorative treatment included direct anterior restorations, direct posterior restorations, inlays, onlays, veneers, crowns, etc.

Types of interventions

The intervention group received a rubber dam for isolation and moisture control, either alone or combined with other active treatment (such as saliva aspiration). The comparison (control) group received an alternative method of isolation and moisture control (such as cotton rolls) with or without the same active treatment as in the intervention group.

Types of outcome measures

Primary outcomes

- Survival rate of the restorations at 6 months, 1, 2, 5 and 10 years after restorative treatments. Survival means the restorations were still correctly present or having only a slight wear or defect at the margin less than 0.5 mm in depth when assessed. If the restorations were either completely lost, or were fractured with defects 0.5 mm in depth or greater, had secondary caries or inflammation of the pulp, any of these situations was labelled as treatment failure.
- Adverse events. Any reported adverse events related to any of the active interventions during the treatment phase. These included events affecting the operator or the patient (e.g. damage to skin or mucosa, allergic reactions to latex).

Secondary outcomes

- Clinical evaluation of restoration's quality, including colour match, cavo-surface marginal discolouration, anatomic form, marginal adaptation and caries, which were assessed at baseline (i.e. within one month following the placement) as well as 6 months, 1, 2, 5 and 10 years of subsequent recalls. The evaluation should be based upon the US Public Health Service (USPHS) criteria and its evolution (Hickel 2007), which had specific clinical criteria followed for the assessment of each category.
- Costs: the direct cost of the treatment, the time needed to accomplish the treatment.
- Participant acceptance/satisfaction. Participants expressed satisfaction with the procedure using any validated instrument.

Search methods for identification of studies

For the identification of studies included or considered for this review, we developed detailed search strategies for each database searched. We based these on the search strategy developed for MEDLINE but revised appropriately for each database to take account of differences in controlled vocabulary and syntax rules. There were no language restrictions in the searches. We translated papers when necessary.

Electronic searches

The search included the following databases:

- Cochrane Oral Health's Trials Register (searched 17 August 2016) (Appendix 1);
- Cochrane Central Register of Controlled Trials (CENTRAL; 2016, Issue 7) in the Cochrane Library (searched 17 August 2016) (Appendix 2);
- MEDLINE Ovid (1946 to 17 August 2016) (Appendix 3);
- Embase Ovid (1980 to 17 August 2016) (Appendix 4);
- LILACS BIREME Virtual Health Library (Latin American and Caribbean Health Science Information database; 1982 to 17 August 2016) (Appendix 5);
- SciELO BIREME Virtual Health Library (Scientific Electronic Library Online; 1998 to 17 August 2016) (Appendix 6);
- Chinese BioMedical Literature Database (CBM, in Chinese) (1978 to 30 August 2016) (Appendix 7);
- VIP (in Chinese, 1989 to 30 August 2016) (Appendix 8);
- China National Knowledge Infrastructure (CNKI, in Chinese) (1994 to 30 August 2016) (Appendix 9).

Searching other resources

Searching for unpublished studies and ongoing studies

We searched the following sources for unpublished and ongoing studies:

- US National Institutes of Health Ongoing Trials Register ClinicalTrials.gov (clinicaltrials.gov/; searched 17 August 2016) (Appendix 10);
- World Health Organization International Clinical Trials Registry Platform (apps.who.int/trialsearch; searched 17 August 2016) (Appendix 10);
- OpenGrey (1980 to 17 August 2016) (Appendix 11);
- Sciencepaper Online (in Chinese, to 30 August 2016) (Appendix 12).

Handsearching

We handsearched the following journals:

- *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology* (1995 to October 2015);
- *Journal of Endodontics* (1975 to October 2015);
- *International Endodontic Journal* (1967 to October 2015);
- *Caries Research* (1967 to October 2015);
- *Journal of Dental Research* (1970 to October 2015);
- *International Journal of Oral Science* (2009 to October 2015);
- *Dental Traumatology* (1985 to October 2015);
- *Australian Endodontic Journal* (1967 to October 2015).

In addition, we explored the following Chinese dental journals:

- *Chinese Journal of Stomatology* (2005 to October 2015);
- *West China Journal of Stomatology* (2005 to October 2015);
- *Journal of International Stomatology* (2005 to October 2015);
- *Journal of Clinical Stomatology* (2005 to October 2015);
- *Journal of Practical Stomatology* (2005 to October 2015);
- *Journal of Comprehensive Stomatology* (2005 to October 2015);
- *Journal of Modern Stomatology* (2005 to October 2015);
- *Chinese Journal of Conservative Dentistry* (2005 to October 2015);
- *Chinese Journal of Dental Prevention and Treatment* (2005 to October 2015).

Reference lists and contacts

We screened the references of the included articles for studies. We contacted authors and experts in the field to identify unpublished randomised controlled trials.

Data collection and analysis

Two review authors (Yan Wang (YW), He Yuan (HY)) independently selected studies, extracted and managed data, and assessed risk of bias. We resolved any differences of opinion by discussion.

Selection of studies

We used a two-step process to identify studies to be included in this review. We screened titles and abstracts from the electronic searches to identify studies which may have met the inclusion criteria for this review. We obtained full-text copies of all apparently eligible studies and two review authors evaluated these further in detail to identify those studies which actually met all the inclusion criteria. We recorded those studies which did not meet the inclusion criteria in the excluded studies section of the review and noted the reason for exclusion in the Characteristics of excluded studies table.

Data extraction and management

We designed and piloted a data extraction form on two included studies. The data extraction form included the following information.

- Article title, publication time, journal, reviewer ID.
- Inclusion re-evaluation.
- Types of studies: methods of randomisation, methods of allocation concealment, methods of blinding, location of the study, number of centres, time frame, source of funding.
- Types of participants: source of participants, types of disease, diagnostic criteria, age, sex, eligibility criteria, numbers of participants randomised to each group, number evaluated in each group.
- Types of intervention and comparison: details of the treatments received in the intervention and comparison groups, together with the type of restoration procedure and any co-interventions used.
- Types of outcome measures: outcome, time point that the outcome was recorded, exact statistics.

Assessment of risk of bias in included studies

The review authors assessed the risk of bias for each included study in each of seven domains using the 'Risk of bias' tool as described in Chapter 8 of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011). For each domain, we presented explanations and judged them as low risk, unclear risk and high risk. The domains and explanations were as follows.

- Random sequence generation (selection bias): selection bias (biased allocation to interventions) due to inadequate generation of a randomised sequence.
- Allocation concealment (selection bias): selection bias (biased allocation to interventions) due to inadequate concealment of the allocation sequence from those involved in the enrolment and assignment of participants.

- Blinding of participants and personnel (performance bias): performance bias due to knowledge of the allocated interventions by participants and personnel during the study.
- Blinding of outcome assessment (detection bias): detection bias due to knowledge of the allocated interventions by outcome assessors.
- Incomplete outcome data (attrition bias): attrition bias due to amount, nature or handling of incomplete outcome data.
- Selective reporting (reporting bias): reporting bias due to selective outcome reporting.
- Other bias: bias due to problems not covered elsewhere in the table.

We categorised the overall risk of bias according to Additional Table 1 and summarised the 'Risk of bias' graphically.

Measures of treatment effect

For the primary outcome of survival/success rate of the restorative treatment, we expressed the measure of the treatment effect as a hazard ratio (HR) or risk ratio (RR) with 95% confidence interval (CI). If the studies did not quote HRs, we calculated the log HRs and the standard errors (SE) from the available summary statistics or Kaplan-Meier curves according to the methods proposed by Parmar and colleagues (Parmar 1998), or requested the data from study authors. For the primary outcome of incidence of adverse events, we used the RR and 95% CIs to estimate the treatment effect.
For the secondary outcomes, we used RR and 95% CIs for dichotomous data and mean difference (MD) and 95% CIs for continuous data.

Unit of analysis issues

The unit of analysis was the participant.

Cross-over/split-mouth trials

We assessed carry-over or carry-across effect of designs if we considered them a problem. For an ideal study (which reported MD and standard deviation (SD) of both groups and the MD together with SD/SE between the two groups), we calculated the intra-cluster correlation coefficient (ICC); if more than one ideal study existed, we calculated a mean ICC. We used this ICC in the calculation of MD and SD/SE of the other similar cross-over/split-mouth studies. If there was no ideal study, we assumed the ICC was 0.5 (Higgins 2011).

Trials with multiple intervention arms

For randomised controlled trials with multiple treatment arms, there were two steps to deal with this problem. First, we tried to combine treatment arms, or we analysed the most relevant treatment and controls groups. For such trials, we collected the data in all the groups and recorded details in the Characteristics of included studies table.

Dealing with missing data

Where information about trial procedures was incomplete or unclear in a trial report, or data were missing or incomplete, the review authors attempted to contact the trial authors to obtain clarification. Where we could not obtain missing data, we did not include the trial in the meta-analysis but described the results narratively. Where SDs were missing from continuous outcome data, we attempted to calculate these based on other available data (e.g. CIs, SEs, t values, P values, F values), as discussed in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011).

Assessment of heterogeneity

We considered two types of heterogeneity.

Clinical heterogeneity

We judged clinical heterogeneity from the similarity between the types of participants, interventions and outcome measures in each trial.

Statistical heterogeneity

We calculated statistical heterogeneity through the Chi^2 test and measured the effect using the I^2 statistic or P value (P value < 0.1 indicated statistically significant heterogeneity). The classification of statistical heterogeneity was as follows.

- 0% to 40% implied slight heterogeneity.
- 30% to 60% moderate heterogeneity.
- 50% to 90% substantial heterogeneity.
- 75% to 100% considerable heterogeneity.

Assessment of reporting biases

We planned to report bias using a funnel plot if the number of included studies had exceeded 10. The asymmetry of the funnel plot would indicate a possibility of reporting bias. Further detection would use Begg's test (Begg 1994) for dichotomous data and Egger's test (Egger 1997) for continuous data.

Data synthesis

We planned to perform meta-analyses only when there were little clinical heterogeneity and statistical heterogeneity (I^2 less than 75%). If the number of studies in one outcome did not exceed four, we planned to use the fixed-effect model; otherwise, we planned to use the random-effects model.

Subgroup analysis and investigation of heterogeneity

If the number of studies in one outcome exceeded 10, we planned to use meta-regression to detect clinical heterogeneity (using STATA 11.0). If there was clinical heterogeneity, we planned to perform subgroup analysis of the following:

- types of restorative treatments;
- age of the participants;
- location of the restoration (anterior/posterior teeth);
- types of adhesives.

Due to the small number of eligible studies and a lack of suitable data from the included studies, we were unable to do subgroup analyses; however, we will consider carrying this out if more eligible studies are included in future updates of this review.

Sensitivity analysis

We planned to perform a sensitivity analysis to detect the stability of the outcomes. If there had been a sufficient number of included trials, we would have based sensitivity analysis on risk of bias (low risk of bias versus high or unclear risk of bias).

Presentation of main results

We developed a 'Summary of findings' table for the reported primary outcomes of this review using GRADEproGDT software (GRADEproGDT). We assessed the quality of the body of evidence with reference to the overall risk of bias of the included studies, the directness of the evidence, the inconsistency of the results, the precision of the estimates, the risk of publication bias, the magnitude of the effect and whether there was evidence of a dose response. GRADE categorises the quality of the body of evidence for each of the primary outcomes as high, moderate, low or very low (Atkins 2004; Guyatt 2008; Higgins 2011).

RESULTS

Description of studies

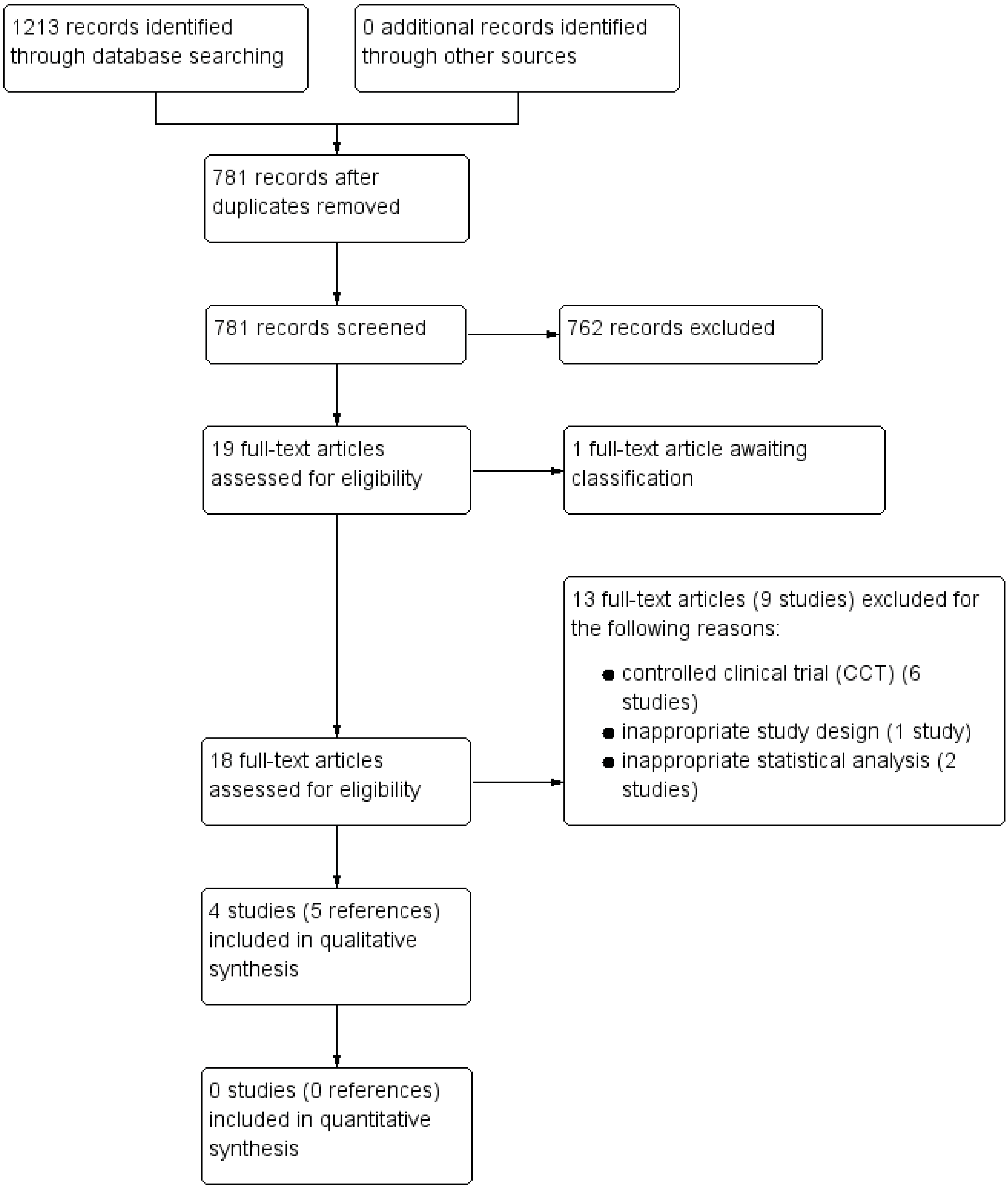
See Characteristics of included studies and Characteristics of excluded studies tables.

Results of the search

The electronic searches retrieved 1213 references, which reduced to 781 after de-duplication. Handsearching of the journals did not identify any additional studies. After reviewing the titles and abstracts, we disregarded 762 references that did not match our criteria and were clearly ineligible. We obtained the full-text copies of the remaining 19 studies for further evaluation. We classified one study into 'studies awaiting classification' as we were waiting responses from the authors on the details of the method of randomisation used, preformation of allocation concealment and the funding sources (Alhareky 2014). We excluded nine studies (13 references). Finally, four studies (five references), including one Chinese study and three English studies, were eligible for inclusion (Ammann 2013; Carvalho 2010; Kemoli 2010; Ma 2012).

We have presented this process as a flow chart in Figure 1.

Figure 1. Study flow diagram.



Included studies

This review included four randomised controlled trials (RCTs), which were published between 2010 and 2013 (Ammann 2013; Carvalho 2010; Kemoli 2010; Ma 2012). *See* Characteristics of included studies table for details of the included studies.

Characteristics of the trial designs and settings

All of the included studies used a parallel design (Ammann 2013; Carvalho 2010; Kemoli 2010; Ma 2012). The studies were conducted in Germany (Ammann 2013), Brazil (Carvalho 2010), Kenya (Kemoli 2010) and China (Ma 2012). One study was carried out in a private dental clinic setting (Ammann 2013), one in a dental hospital setting (Ma 2012), and two in a school setting (Carvalho 2010; Kemoli 2010). One study performed a sample size calculation; however, the study did not mention the method used (Kemoli 2010). The other three studies did not mention sample size calculations (Ammann 2013; Carvalho 2010; Ma 2012). Two studies did not state their funding sources (Ma 2012), and one study stated that they received both industry and non-industry funding (Kemoli 2010). The remaining studies stated that they received industry funding (Ammann 2013) or non-industry funding (Carvalho 2010).

Characteristics of the participants

The trials included 1270 participants (among which 233 participants were lost to follow-up) with different age ranges and receiving various restorative treatments. Ammann 2013 included 72 children aged 5.9 to 11.9 years who undertook fissure sealing of premolars or molars. Ma 2012 studied 162 participants (162 teeth) with non-carious cervical lesions (NCCLs) receiving resin composite restoration, without mentioning the age range and sex ratio. Two studies included children undertaking proximal primary atraumatic restorative treatment (ART) restorations in primary molars. These two studies included 804 children aged six to eight years (Kemoli 2010), and 232 children aged six to seven years (Carvalho 2010). All the participants of these included studies received direct dental restorative treatments.

Characteristics of the interventions

The active intervention in each of the included trials was rubber dam isolation in dental restorative treatments. All of the included trials used a comparison group of cotton rolls as the alternative isolation method.

Characteristics of the outcome measures

None of the included studies reported both primary outcomes. Three studies reported the survival rate or failure rate of the restorations (Additional Table 2) (Carvalho 2010; Kemoli 2010; Ma 2012). There was variability between the studies in their criteria for "survival or failure of the restorations". Carvalho 2010 and Kemoli 2010 defined "survival of the restorations" as the restorations being present with marginal defects 0.5 mm or less in depth and general wear 0.5 mm or less in depth at the deepest point. Ma 2012 defined "failure" as the restoration being absent at the time of evaluation. None of the three studies reported adverse effects. Ammann 2013 did not report survival rate or adverse effects.

None of the included studies evaluated the quality of the restorations, the direct cost of the treatment or the level of participant acceptance/satisfaction. Ammann 2013 evaluated the treatment time when using rubber dam or cotton rolls as the isolation method in fissure sealing.

Excluded studies

We listed all the excluded studies and the reasons for their exclusion in the Characteristics of excluded studies table.

Six studies were controlled clinical trials (CCT) (Ganss 1999; Huth 2004; Sabbagh 2011; Smales 1993; Straffon 1985; van Dijken 1987). Three studies used either an inappropriate study design or an inappropriate statistical analysis (Daudt 2013; Fontes 2009; Raskin 2000). Daudt 2013 and Raskin 2000 performed randomisation and analysis at the tooth level without accounting for the clustering effect of teeth within individual participants. For Fontes 2009, the study claimed to be performed using a split-mouth design, but it was not carried out it in an appropriate way.

Risk of bias in included studies

All of the included studies were at high risk of bias overall, based on a judgement of high risk of bias for two domains (Ammann 2013; Carvalho 2010; Kemoli 2010), or one domain (Ma 2012). Details of the assessments made of these studies are available in the 'Risk of bias' section of the Characteristics of included studies table and in the 'Risk of bias' graph (Figure 2) and 'Risk of bias' summary (Figure 3).

Figure 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

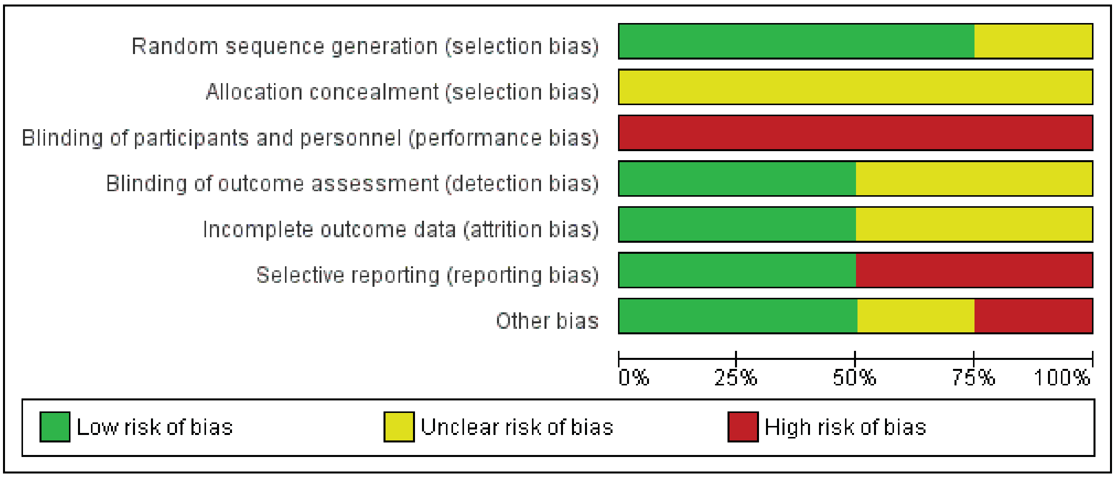
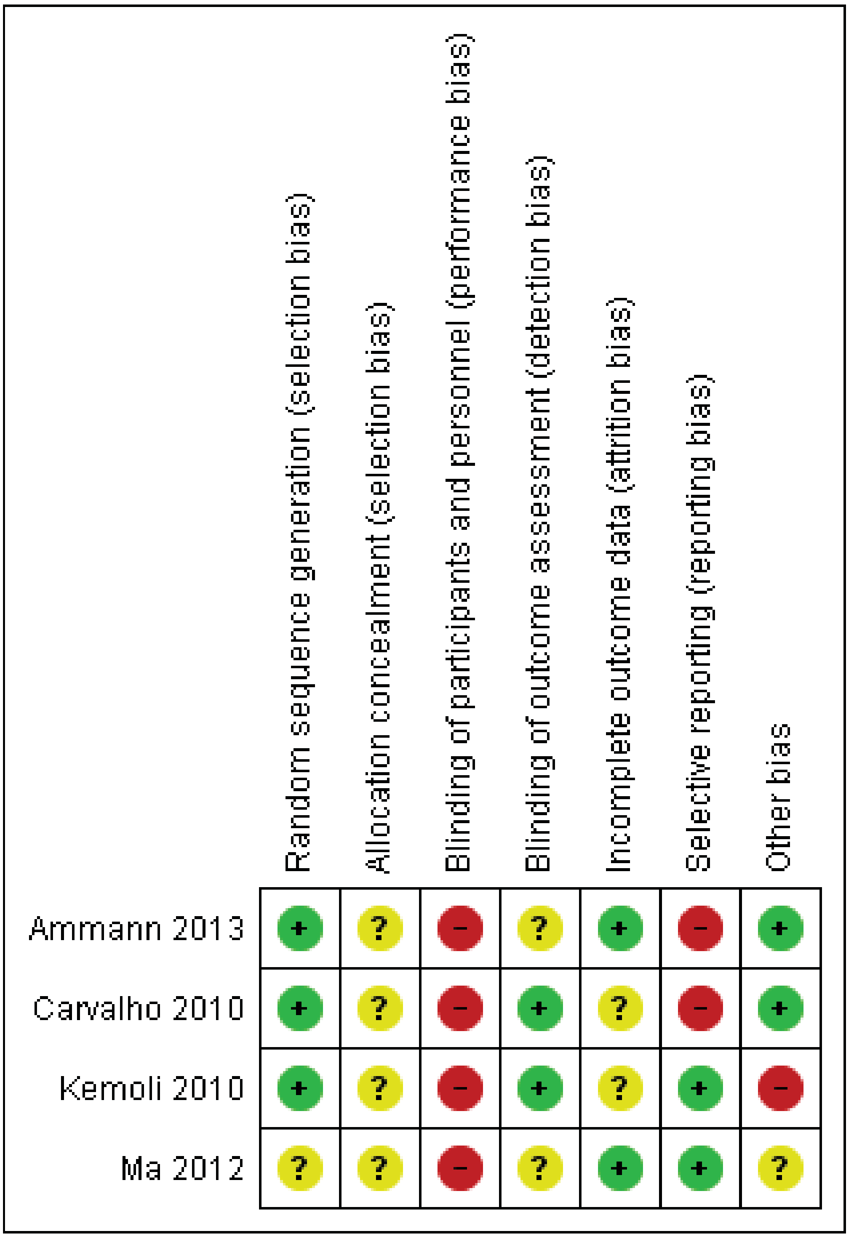


Figure 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.



Allocation

Method of randomisation

Ammann 2013, Carvalho 2010, and Kemoli 2010 clearly stated the methods of randomisation used in the references. Thus, we assessed these three studies at low risk of bias. We judged Ma 2012 at unclear risk of bias in its method of randomisation, because there was insufficient information to make a clear judgement.

Allocation concealment

We were unable to make a judgement of high or low risk of bias for allocation concealment as it was not adequately reported in the included studies (Ammann 2013; Carvalho 2010; Kemoli 2010; Ma 2012).

Blinding

We judged all of the included studies at high risk of performance bias, because the types of interventions did not permit blinding of the operators or the participants (Ammann 2013; Carvalho 2010; Kemoli 2010; Ma 2012).
We assessed two studies at low risk of detection bias (Carvalho 2010; Kemoli 2010). In Carvalho 2010, they explicitly reported the blinding of outcome assessors; and in Kemoli 2010, as the authors clearly stated that the outcome assessors were calibrated and were not the operators, we believed that the outcome assessors had high possibility of being blinded. The remaining studies were at unclear risk of bias in the blinding of outcome assessment, because they did not mention the blinding of outcome assessors (Ammann 2013; Ma 2012).

Incomplete outcome data

We judged attrition bias as being low in two studies, because they reported no losses to follow-up (Ammann 2013; Ma 2012). Kemoli 2010 reported that 19.1% of the participants were lost to follow-up, but did not provide information about the distribution of attrition between treatment groups. Thus, we assessed this study as having an unclear risk of bias for this domain. We also judged Carvalho 2010 at unclear risk of bias, because the reasons for the exclusions of participants were not fully described even though the number of exclusions in each group was comparable (14.7% in the control group and 18.5% in the rubber dam group). The cut-off points used for deciding the risk of attrition bias may be subjective; therefore, readers of this review could interpret the risk of bias for this domain differently.

Selective reporting

We considered two studies as being at high risk of bias in reporting data (Ammann 2013; Carvalho 2010). In Ammann 2013, the authors did not fully report the data on the treatment time in fissure sealing; and in Carvalho 2010, as the survival/failure rate was not consistent with the number of restorations considered as success or failure presented, we were unable to use the data for analysis. We assessed the studies of Kemoli 2010 and Ma 2012 at low risk of bias for reporting bias, because they fully reported all the prespecified outcomes.

Other potential sources of bias

Ma 2012 did not report the characteristics of participants to allow an assessment of the comparability of the treatment and control groups at baseline. Thus, we judged this study at unclear risk of bias for this domain. We considered Ammann 2013 and Carvalho 2010 at low risk of bias for other potential sources of bias, because they reported the comparability of the treatment and control groups at baseline. In Kemoli 2010, there was a substantial baseline imbalance in the dental arch between rubber dam and cotton roll isolation groups, which might have influenced the performance of the restorations, so we assessed this study at high risk of bias for other potential sources of bias.

Effects of interventions

See: **Summary of findings for the main comparison** Rubber dam versus cotton rolls for restorative treatment in dental patients

Rubber dam versus cotton rolls

Four studies, at high risk of bias, compared rubber dam isolation method with cotton rolls as the alternative isolation method, and evaluated 1037 participants.

Primary outcomes

Survival rate of the restorations

Three studies reported the survival/loss rate of the restorations (Additional Table 2). One study reported the loss rate of the restorations (Ma 2012). The analysis indicated that rubber dam usage resulted in a higher retention rate of restorations in participants with NCCLs receiving resin composite restorative treatment at six months (risk ratio (RR) 1.19, 95% confidence interval (CI) 1.04 to 1.37, 162 participants, very low-quality evidence) (Analysis 1.1). Two studies reported the survival rates of the restoration (Carvalho

2010; Kemoli 2010). Carvalho 2010 reported the cumulative survival rate of dental restorations at 6, 12, 18 and 24 months. However, the number of restorations reported to have been performed at the start of the evaluation period and the number of restorations failed at the end of the evaluation period were not consistent with the reported survival rate. Due to these inconsistencies, we were unable to include the data of this study in our analyses. Kemoli 2010 found a significant difference in the survival rate of dental restorations was observed at two years in favour of rubber dam usage (hazard ratio (HR) 0.80, 95% CI 0.66 to 0.97, 559 participants, very low-quality evidence) (Analysis 1.2).

Adverse events

None of the included studies reported adverse events.

Secondary outcomes

Clinical evaluation of restoration's quality

None of the included studies evaluated the quality of the restorations.

Costs

One study, at high risk of bias evaluating 72 children, reported 12.4% less time (108 seconds) needed to accomplish fissure sealing using rubber dam compared to using cotton rolls as the isolation method (Ammann 2013). None of the included studies reported the direct cost of treatment.

Participant acceptance/satisfaction

None of the included studies reported the level of participant acceptance/satisfaction.

DISCUSSION

Summary of main results

Four studies met the inclusion criteria for this review, and all of these studies evaluated the effects of rubber dam versus cotton roll isolation methods on the direct restorative treatments in dental patients, including fissure sealing in permanent premolars or molars, proximal atraumatic restorative treatment (ART) in primary molars and composite resin restoration of non-carious cervical lesions (NCCLs) in permanent teeth. We assessed the quality of the body of evidence based upon the GRADE approach, which takes into account the risk of bias of the included studies, the directness of the evidence, the consistency of the results (heterogeneity), the precision of the effect estimates and the risk of publication bias (GRADE 2004). We have provided a summary of this quality assessment for survival rates at six months and two years (Summary of findings for the main comparison).

There was very low-quality evidence, from single studies, indicating that rubber dam isolation may favour a higher survival rate or a lower loss rate of restorations during dental direct restorative treatments.

- Rubber dam compared with cotton rolls in resin composite restorative treatments of NCCLs (very low-quality evidence) (Ma 2012).
- Rubber dam compared with cotton rolls in proximal ART restorative treatments in primary molars (very low-quality evidence) (Kemoli 2010).

We did not analyse the data for rubber dam versus cotton rolls in Carvalho 2010, because we found inconsistencies of reported data. Ammann 2013 did not evaluate the survival rate of fissure sealants. None of the included studies reported adverse events.

Overall completeness and applicability of evidence

The identified studies in the review did not address the objectives of the review sufficiently. Four studies were eligible for inclusion, and they only investigated participants receiving fissure sealing, resin composite restorations of NCCLs and proximal ART restorative treatments. We found no eligible randomised controlled trials (RCTs) of participants receiving other types of restorative treatments such as inlays, onlays, etc. Furthermore, none of the included studies fully reported the outcomes and the evidence was incomplete regarding the outcomes. There were no included studies evaluating the quality of the restorations or reporting adverse effects, the direct cost of the treatment, or the level of participant acceptance/satisfaction, which are important aspects in rubber dam usage (Hill 2008; Koshy 2002; Stewardson 2002). Although three of the included studies reported the survival/loss rate, we could not pool the outcomes to address this primary outcome due to inconsistent data presentation, differences in the restorative treatments carried out, different follow-up time points, or different criteria used for the definition of 'survival/failure' among them.

Quality of the evidence

The body of evidence that we identified did not allow for robust conclusions about the effects of rubber dam isolation for restorative treatment to be made. We included four studies, which analysed 1037 participants. We excluded one study from analysis due to inconsistencies in the presented data (Carvalho 2010). The remaining three studies were at high risk of bias (Ammann 2013;

Kemoli 2010; Ma 2012). When such risk of bias issues were considered alongside the fact that the study in each comparison/outcome was a single small study (leading to serious imprecision), this resulted in us rating the evidence as very low quality. These GRADE ratings can be interpreted as a lack of confidence in the effect estimates. Further research is likely to change the estimates and our confidence in them.

Potential biases in the review process

We searched multiple databases with no language restrictions, intending to limit bias by including all relevant studies. However, we did not include all of the included studies into the analysis, and this could introduce bias into the review as it may distort our overall view of the effects of the rubber dam isolation method. Our subjective assessments that a loss to follow-up of more than 20% constitutes a high attrition rate could also be interpreted as bias by some readers. However, we have presented all the related information, rationales for the method used, and our assessments with the intention of transparency and to allow the readers to reach their own conclusion.

Agreements and disagreements with other studies or reviews

To our knowledge, one systematic review has studied the influence of different operatory field isolation techniques on the longevity of dental restorations (Cajazeira 2014). Their inclusion criteria differed from the inclusion criteria of this review in that they only included studies evaluating the effects of the operatory field isolation techniques (rubber dam or cotton rolls/saliva ejector) on the longevity of direct restorations performed with tooth-coloured materials in primary or permanent posterior teeth, and having a follow-up period of at least 12 months. Moreover, the Cajazeira 2014 review included two studies that we excluded: Huth 2004, which we excluded since randomised allocation of participants was not performed between the two isolation groups in the study, and Raskin 2000, which we excluded due to inappropriate statistical analysis (randomisation and analysis at tooth level without accounting for the clustering effect of teeth within participants). They finally included four studies into the analysis (Carvalho 2010; Huth 2004; Kemoli 2010; Raskin 2000), and concluded that the use of rubber dam might not influence the longevity of restorations in comparison to using cotton rolls/saliva ejector.

AUTHORS' CONCLUSIONS

Implications for practice

We found some very low-quality evidence, from single studies, suggesting that rubber dam usage in dental direct restorative treatments may lead to a higher survival rate of the restorations. The effect estimate should be interpreted with caution due to a high risk of bias in the analysed studies, the small number of included studies and that the type of restorative treatments varied among studies. This review found no evidence to support or refute any adverse effects that the rubber dam isolation method may have on patients.

Although there was no robust evidence to favour rubber dam usage in improving the survival rate of restorations, this does not mean that rubber dam usage is not important during restorative treatments, since the clinical decision is not solely based upon its ability to reduce failure rate of restorations. The use of rubber dam still has numerous advantages, such as preventing accidental swallowing of restorative instruments or tooth fragments, protecting soft tissues from sharp instruments, or helping in behaviour management in children. Clinicians still need to practice rubber dam placement, and never using a rubber dam would not be an acceptable approach.

Implications for research

The fact that we are unable to make a robust conclusion on the effect of using rubber dam isolation during restorative treatments in dental patients demonstrates that more randomised controlled trials with longer follow-up periods are needed. In particular, we identified no studies that investigated the effects of the isolation methods on the performance of indirect restorations. Further properly designed high quality research is required, as we excluded a few studies due to inappropriate statistical analysis, such as performing randomisation and analysis at tooth level without accounting for the clustering effect of teeth within participants. Studies should report the survival rate of restorations and perform clinical evaluation of the quality of the restorations based upon US Public Health Service criteria. Adverse effects, participant acceptance/satisfaction and the direct cost of the treatment should also be clearly reported at the participant level per group.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Ammann 2013

Methods	Design: parallel-group RCT Recruitment period: not stated Administration setting: private dental clinic Country: Germany Funding source: Dentsply DeTrey, Konstanz, Germany
Participants	Number of participants randomised: 72 (rubber dam: 34; cotton rolls: 38) Randomisation unit: participant Age: 5.9 to 16.9 years, mean age 11.1 years Sex: 23 boys, 49 girls Inclusion criteria: • aged 6 to 16 years • given indication for fissure sealing Exclusion criteria: • participation in other studies evaluating parameters of stress • not totally erupted teeth to seal • lack of compliance • no agreement from the guardians • presence of fixed orthodontic appliances • signs of opacity and brown discolouration of the tooth to be sealed • psychotropic medication or cardiovascular drugs • already sealed teeth • present disease (cold) • allergic reactions to used materials Restorative treatments received: fissure sealing in premolar/molar Number of participants evaluated: 72 (rubber dam: 34; cotton rolls: 38) Withdrawals/loss to follow-up: no withdrawals
Interventions	Number of groups: 2 Intervention: rubber dam: "A suitable rubber dam clamp (Ivoryò; Sigma Dental Systems, Handewitt, Germany) was selected and applied. Afterwards, the rubber dam was placed over the clamp. Several teeth were included in the rubber dam in cases involving premolars, whereas for molars only the treated tooth was isolated" Control: cotton rolls: "The cotton rolls were positioned on the buccal and lingual region of the tooth to be sealed and were fixed by the operator's index finger and middle finger. Additionally, a saliva ejector was placed on the lingual side"
Outcomes	Outcomes: treatment time
Notes	Adverse events: not stated No details on sample size or power calculation were provided

Risk of bias	***Risk of bias***

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "72 subjects successfully took part in the study and were divided into two parallel groups by a dental assistant by drawing sealed lots (test n = 34; control n = 38)" Comment: method stated and appropriate
Allocation concealment (selection bias)	Unclear risk	Not stated Comment: insufficient information reported to make a judgement
Blinding of participants and personnel (performance bias) All outcomes	High risk	Comment: the operators and the participants could not be blinded
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not stated Comment: insufficient information reported to make a judgement
Incomplete outcome data (attrition bias) All outcomes	Low risk	Comment: no withdrawals
Selective reporting (reporting bias)	High risk	Quote: "The time needed to finish the fissure sealing treatment was 12.4% (108 s [seconds]) less when using rubber dam (P < 0.05)" Comment: insufficient information reported to use the data in the analysis
Other bias	Low risk	Comparable groups at baseline (age, gender, type of teeth treated)

Carvalho 2010

Methods	Design: parallel-group RCT Recruitment period: not stated Administration setting: schools Country: Brazil Funding source: the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)
Participants	Number of participants randomised: 232; 232 teeth (rubber dam: 115; cotton rolls: 117) Randomisation unit: participant/tooth Age: 6 to 7 years, mean age 6.3 years Sex: 128 boys, 104 girls Inclusion criteria: • aged 6 to 7 years

	• proximal lesions having access to ART hand instruments, with a mesio-distal maximum dimension of 1 mm and a buccal-lingual maximum dimension of 2 mm length, measured on the occlusal surface using a periodontal probe • lesions with unimpaired adjacent tooth Exclusion criteria: • cavitated carious lesions having pulpal involvement, swelling, fistula or pain Restorative treatments received: proximal ART restorations in primary molar Number of participants evaluated: 155 (rubber dam: 72 teeth; cotton rolls: 83 teeth) Withdrawals/loss to follow-up: 77 children in total. 48 children were unavailable at the time of assessment. 29 children lost their teeth due to exfoliation or extraction
Interventions	Number of groups: 2 Intervention: rubber dam: "For the experiment group, a rubber dam was used, fixed with a clamp on the adjacent distal tooth without local anaesthesia" Control: cotton rolls: "New cotton rolls were placed on both sides of the molar without local anaesthesia"
Outcomes	Outcomes: failure rate/cumulative survival rate of restorations Time points: 6, 12, 18 and 24 months after restoration placement Diagnostic criteria: restorations assessed according to the following criteria: • successful treatment: when it was still present and correct or having only a slight wear or defect at the margin < 0.5 mm in depth • treatment failures: when the restorations were either completely lost, or were fractured with defects $\geq$ 0.5 mm in depth, had secondary caries, or inflammation of the pulp • lost to follow-up: when the children who were not found at the time of assessment, or when the teeth were lost to exfoliation or extraction
Notes	Adverse events: not stated No details on sample size or power calculation provided The survival/failure rate was not consistent with the number of restorations considered as success or failure presented in table 1 of the report. We were unable to use the data in the analysis

Risk of bias ***Risk of bias***

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "Each child was individually allocated into a group by the use of generated random numbers, and no restrictions were considered" Comment: method stated and appropriate
Allocation concealment (selection bias)	Unclear risk	Quote: "Each child was individually allocated into a group by the use of generated random numbers, and no restrictions were considered. The group in charge of making the restorations or those who assessed the

Carvalho 2010 (*Continued)*

		restorations did not have access to the randomizations procedure. All children were allocated into the respective group before the restorations were made" Comment: sequence allocation was not adequately described
Blinding of participants and personnel (performance bias) All outcomes	High risk	Comment: the operators and the participants could not be blinded
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "These examiners were blinded to the exposure categories. In other words, at the time of examination of the restoration, the examiners did not know to which group the child belonged to" Comment: examiners were blinded
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Quote: "Throughout the study, a total of 48 (20.7%) children were considered as lost to follow-up. Others eventually lost their teeth due to exfoliation or extraction. Due to such reasons, a total of 77 restorations (33.2%) were censored (lost to follow-up) , where 34 (14.7%) were from the control group and 43 (18.5%) from the rubber dam group (χ^2 [Chi^2] = 1.82; df [degrees of freedom] = 1; P = 0.18)" Comment: loss to follow-up was high (overall 33.2%) and reasons for loss to follow-up (20.7%) were not explicitly explained
Selective reporting (reporting bias)	High risk	Comment: survival/failure rate was not consistent with the number of restorations considered as success or failure presented in table 1. We were unable to use the data in the analysis
Other bias	Low risk	Comment: groups at baseline (age, gender, jaw, molar and operator) comparable

Kemoli 2010

Methods	Design: parallel-group RCT Recruitment period: not stated Administration setting: public primary schools Country: Kenya Funding source: Netherlands Universities' Foundation for International Cooperation (NUFFIC), financial support from the University of Nairobi, GC Europe and 3M ESPE (Netherlands)
Participants	Number of participants randomised: 804; 804 teeth (rubber dam: 404; cotton rolls: 397) Randomisation unit: participant/tooth Age: 6 to 8 years Sex: 454 boys, 350 girls Inclusion criteria: • aged 6 to 8 years • in good general health • a proximal carious lesion in a primary molar having an occlusal access of approximately 0.5 mm to 1.0 mm in the bucco-lingual direction Exclusion criteria: not stated Restorative treatments received: proximal ART restorations in primary molars. Fuji IX (GC Europe) or Ketac Molar Easymix or KME (3M ESPE AG); Ketac Molar Aplicap or KMA (3M ESPE AG) Number of participants evaluated: 648 (number in each group not stated) Withdrawals/loss to follow-up: • overall 156 (19.4%) • 3 (0.4%) cases that were improperly documented • 38 (4.7%) could not be evaluated after placement because of truancy • 115 (14.3%) withdrawals due to drop-outs, school-transferees, absentees and 1 death
Interventions	Number of groups: 2 Intervention: rubber dam: "The rubber dam (Medium-dark, Hygenic Dental Dam, HCM - Hygienic Corporation, Malaysia) was used to isolate the tooth to be restored. A 2-minute gingival application of a topical anaesthetic (Lidocaine 50mg/g cream) was used prior to the application of the rubber dam clamp (FIT - Kofferdam Klammer, U67, Hager & Werken GmbH & Co. KG Germany). No other local analgesic was used in the study" Control: cotton rolls: "The cotton wool rolls were place buccally (maxillary teeth) or lingually and buccally (mandibular teeth)"
Outcomes	Outcomes: survival rate of restorations Time points: within 2 hours of restoring each tooth, after 1 week, and 1, 5, 12, 18 and 24 months after the restoration Diagnostic criteria: restorations categorised as 0, 1 and 6 had survived; 2, 3, 7, 9 had failed; and 4, 5 and 8 were censored. 0 = present, good. 1 = present, marginal defects ≤ 0.5 mm in depth. 2 = present with marginal defects > 0.5 mm deep. 3 = not present, restoration almost or completely disappeared. 4 = not present, other restoration present. 5 = not present, tooth extracted/exfoliated. 6 = present, general wear over the restoration of ≤ 0.5 mm at the deepest point. 7 = present, general wear over the restoration of > 0. 5 mm. 8 = undiagnosable. 9 = presence of secondary caries in relation to restoration

Notes	Adverse events: not stated Sample size: calculated sample size was 382, but no details provided

Risk of bias

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "Using random numbers, the children were assigned to an isolation method, material, operator and assistant. Each child had the restoration randomly placed in the primary molar in either mandibular or maxillary arch" Comment: method stated and appropriate
Allocation concealment (selection bias)	Unclear risk	Not stated Comment: insufficient information reported to make a judgement
Blinding of participants and personnel (performance bias) All outcomes	High risk	Comment: operators and participants could not be blinded
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Quote: "The evaluators had not restored the cavities but had been trained and calibrated in the technique" Comment: operators were not the assessors
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Quote: "Save for 3 cases that were improperly documented. Because of truancy 38 (4.7%) of the restorations the 801 documented cases could not be evaluated soon after placement, leaving only 763 restorations to be evaluated. Due to the study-population attrition resulting from drop-outs, school-transferees, absentees and one death, only 648 (80.9%) children could be evaluated at the end of 2 years" Comment: overall losses < 20%, and reasons were listed. However, no details on the number and reasons of withdrawals in each group given
Selective reporting (reporting bias)	Low risk	Comment: outcomes were reported as planned

Kemoli 2010 (*Continued*)

Other bias	High risk	Comment: groups at baseline (dental arch) not comparable 405 restorations were isolated with rubber dam, 101 of which were restorations in the mandible; and 397 were isolated with cotton rolls, 141 of them were restorations in the mandible (Fisher's Exact Test, P = 0.001)

Ma 2012

Methods	Design: parallel-group RCT Recruitment period: 2009 to 2011 Administration setting: dental clinical of hospital Country: China Funding source: not stated
Participants	Number of participants randomised: 162; 162 teeth (rubber dam: 81; cotton rolls: 81) Randomisation unit: participant/tooth Age: not stated Sex: not stated Inclusion criteria (as translated): • with NCCLs in mandibular premolars • in dentine but without pulp exposure • lesions above the gingival margins • teeth with NCCLs having no occlusal trauma • teeth with NCCLs having vital pulps Exclusion criteria: not stated Restorative treatments received (as translated): composite restorations of NCCLs Number of participants evaluated: 162; 162 teeth (rubber dam: 81; cotton rolls: 81) Withdrawals/loss to follow-up: no losses to follow-up
Interventions	Number of groups: 2 Intervention: rubber dam (as translated): "isolated with rubber dam (Optra Dam, Ivoclar Vivadent, 0.22 ~ 0.27mm)" Control: cotton rolls (as translated): "isolated with cotton rolls placed in buccal and lingual vestibule"
Outcomes	Outcomes (as translated): failure rate Time points: 6 months after restorative treatment Diagnostic criteria: failure criteria (as translated): restorations found not to exist was regarded as failure. No further detail was provided
Notes	Adverse events: not stated Sample size calculation: no details reported

Risk of bias ***Risk of bias***

Ma 2012 (*Continued)*

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Quote (as translated): "One hundred and sixty-two patients with non-carious cervical lesions were stratified randomly distributed into two groups (n = 81) from June 2009 to June 2011" Comment: method of sequence generation not stated. Insufficient information reported to make a judgement
Allocation concealment (selection bias)	Unclear risk	Not stated Comment: insufficient information reported to make a judgement
Blinding of participants and personnel (performance bias) All outcomes	High risk	Comment: operators and participants could not be blinded
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not stated Comment: insufficient information reported to make a judgement
Incomplete outcome data (attrition bias) All outcomes	Low risk	Comment: no loss to follow-up
Selective reporting (reporting bias)	Low risk	Comment: outcomes reported as planned
Other bias	Unclear risk	Comment: no data on group comparability

ART: atraumatic restorative treatment; NCCLs: non-carious cervical lesions; RCT: randomised controlled trial.

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Daudt 2013	Inappropriate statistical analysis (randomisation and analysis at tooth level without accounting for the clustering effect of teeth within individual participants)
Fontes 2009	Inappropriate study design. The study authors kindly provided us with a prepublication copy of the study and we were able to see that the study claimed to be performed using a split-mouth design, but not carried out it in an appropriate way
Ganss 1999	Randomisation allocation not performed between the rubber dam and cotton rolls isolation groups

(*Continued)*

Huth 2004	Study was a CCT as randomisation allocation was not performed between the 2 treatment groups, and using teeth as the analysis unit
Raskin 2000	Inappropriate statistical analysis (randomisation and analysis at tooth level without accounting for the clustering effect of teeth within individual participants)
Sabbagh 2011	Conference abstract without mentioning randomisation allocation between the 2 treatment groups, and author contact failed
Smales 1993	Study was a CCT as randomisation allocation was not performed between the 2 treatment groups, and using teeth as the analysis unit
Straffon 1985	Randomisation allocation not performed between the rubber dam and cotton roll isolation groups and using tooth surfaces as the analysis unit
van Dijken 1987	Study was a CCT as randomisation allocation was not performed between the 2 treatment groups

CCT: controlled clinical trial.

Characteristics of studies awaiting assessment *[ordered by study ID]*

Alhareky 2014

Methods	Design: split-mouth Recruitment period: not reported Administration setting: teaching clinic of dental school Country: USA Funding source: in part by US Department of Health and Human Services Health Resources and Services Administration grant D84HP19955
Participants	Number of participants randomised: 42; 168 teeth (rubber dam: 84; Isolite system: 84) Randomisation unit: teeth Age: 7 to 16 years, mean age 12.3 years Sex: 19 boys, 23 girls Inclusion criteria: • healthy children with no compromising medical or physical condition • aged 7 to 16 years • children with ≥ 1 caries-free permanent molar in each quadrant, with normal anatomy that qualified for the application of pit and fissure sealants • co-operative children Exclusion criteria: • history of chronic disease • unable to return for follow-ups • requiring < 4 pit and fissure sealants on permanent molars • children with partially erupted molars

Alhareky 2014 (*Continued*)

	Restorative treatments received: pit and fissure sealing of permanent molar Number of participants evaluated: 42; 168 teeth (rubber dam: 84; Isolite system: 84) Withdrawals/loss to follow-up: no loss to follow-up
Interventions	Number of groups: 2 Intervention: RD: "First, gingival soft tissue surrounding the tooth was dried. Topical anesthesia was achieved using 20 percent benzocaine gel, which was applied for one minute, according to the manufacturer's instructions. A wingless clamp appropriate for use on molars was selected and then used in conjunction with a latex-free RD sheet. No bite block was used with the RD" Control: IS: "First, the isthmus (narrow part in the middle of the IS plastic mouthpiece) was placed at the corner of mouth, and the patient was instructed to open widely. The IS mouthpiece was then inserted while folding the cheek shield forward toward the tongue retractor and sliding the isthmus into the cheek. The patient was asked to bite on the bite block part of the IS. Finally, the cheek shield was tucked into the buccal vestibule, and the tongue retractor was tucked into the tongue vestibule. The high-speed evacuation system was connected to the IS system, and a second high-speed suction was used to evacuate the mouth during the sealant placement application"
Outcomes	Treatment time, patient acceptance (evaluated using a questionnaire)
Notes	Adverse events: not reported Sample size calculation: not reported Awaiting responses from authors on the details of the method of randomisation used, preformation of allocation concealment and funding sources

IS: Isolite system; RD: rubber dam.

DATA AND ANALYSES

Comparison 1. Rubber dam versus cotton rolls

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Survival rate (6 months)	1	162	Risk Ratio (M-H, Fixed, 95% CI)	1.19 [1.04, 1.37]
2 Survival rate (24 months)	1	559	Hazard Ratio (Fixed, 95% CI)	0.80 [0.66, 0.97]

Analysis 1.1. Comparison 1 Rubber dam versus cotton rolls, Outcome 1 Survival rate (6 months).

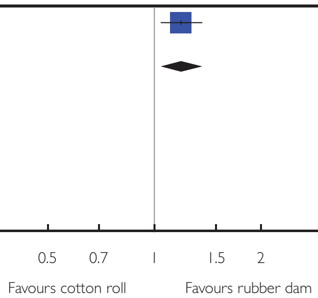
Review: Rubber dam isolation for restorative treatment in dental patients

Comparison: 1 Rubber dam versus cotton rolls

Outcome: 1 Survival rate (6 months)

Study or subgroup	Rubber dam n/N	Cotton roll n/N	Risk Ratio M-H,Fixed,95% CI	Weight	Risk Ratio M-H,Fixed,95% CI
Ma 2012	74/81	62/81		100.0 %	1.19 [1.04, 1.37]
Total (95% CI)	**81**	**81**		**100.0 %**	**1.19 [1.04, 1.37]**

Total events: 74 (Rubber dam), 62 (Cotton roll)
Heterogeneity: not applicable
Test for overall effect: Z = 2.51 (P = 0.012)
Test for subgroup differences: Not applicable



Analysis 1.2. Comparison 1 Rubber dam versus cotton rolls, Outcome 2 Survival rate (24 months).

Review: Rubber dam isolation for restorative treatment in dental patients

Comparison: 1 Rubber dam versus cotton rolls

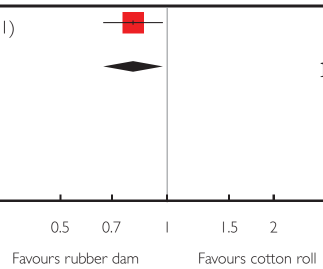
Outcome: 2 Survival rate (24 months)

Study or subgroup	Rubber dam N	Cotton roll N	log [Hazard Ratio] (SE)	Hazard Ratio IV,Fixed,95% CI	Weight	Hazard Ratio IV,Fixed,95% CI
Kemoli 2010	303	256	-0.224 (0.1)		100.0 %	0.80 [0.66, 0.97]
Total (95% CI)	**303**	**256**			**100.0 %**	**0.80 [0.66, 0.97]**

Heterogeneity: not applicable

Test for overall effect: Z = 2.24 (P = 0.025)

Test for subgroup differences: Not applicable



ADDITIONAL TABLES

Table 1. Category of overall risk of bias

Risk of bias	Interpretation	Within a study	Across studies
Low risk of bias	Plausible bias unlikely to seriously alter the results	Low risk of bias for all key domains	Most information is from studies at low risk of bias
Unclear risk of bias	Plausible bias that raises some doubt about the results	Unclear risk of bias for $\geq$ 1 key domains	Most information is from studies at low or unclear risk of bias
High risk of bias	Plausible bias that seriously weakens confidence in the results	High risk of bias for $\geq$ 1 key domains	The proportion of information from studies at high risk of bias is sufficient to affect the interpretation of results

Table 2. Effects of intervention: survival/loss rate

Study ID	Restorative treatment	Time points	Result parameters	Results	Comment
Ma 2012	Composite restorations of NCCLs	6 months after the restoration	Loss rate	Lower failure rate in rubber dam group	Chinese reference, translated

Table 2. Effects of intervention: survival/loss rate *(Continued)*

Carvalho 2010	Proximal ART restorations in primary molar	6, 12, 18 and 24 months after the restoration	Cumulative survival rate of restorations	Both groups had similar survival rate	Excluded from analysis due to inconsistent data
Kemoli 2010	Proximal ART restorations in primary molars	Within 2 hours, 1 week, 1 month, 5 months, 1 year, 1.5 and 2 years after the restorations	Survival rate of restorations	Significant higher 2-year survival rate was observed in rubber dam group compared to cotton roll isolation group	-

ART: atraumatic restorative treatment; NCCLs: non-carious cervical lesions.

APPENDICES

Appendix 1. Cochrane Oral Health's Trials Register

("rubber dam*" or "oral dam*" or "dental dam*" or "latex dam*" or Kofferdam* or "Optra dam*" or "Optradam Plus" or Optidam* or Flexidam* or "Hygenic Fiesta")

Appendix 2. Cochrane Central Register of Controlled Trials (CENTRAL) search strategy

#1 MeSH descriptor Dental restoration, permanent explode all trees
#2 MeSH descriptor Dental restoration, temporary explode all trees
#3 ((dental in All Text near/5 restor* in All Text) or (teeth in All Text near/5 restor* in All Text) or (tooth in All Text near/5 restor* in All Text) or (dental in All Text near/5 fill* in All Text) or (teeth in All Text near/5 fill* in All Text) or (tooth in All Text near/5 fill* in All Text))
#4 MeSH descriptor Dental atraumatic restorative treatment this term only
#5 ((dental in All Text or tooth in All Text or teeth in All Text) and ("atraumatic restorative treatment" in All Text or ART in All Text))
#6 MeSH descriptor Dental amalgam this term only
#7 MeSH descriptor Glass ionomer cements this term only
#8 ((dental in All Text or tooth in All Text or teeth in All Text) and (restor* in All Text and (inlay in All Text or in-lay in All Text or onlay in All Text or on-lay in All Text or post* in All Text or dowel* in All Text or pin* in All Text)))
#9 ((dental in All Text or tooth in All Text or teeth in All Text) and (amalgam* in All Text or resin* in All Text or cement* in All Text or ionomer* in All Text or compomer* in All Text or composite* in All Text))
#10 MeSH descriptor Crowns explode all trees
#11 ((dental in All Text near/5 crown* in All Text) or (tooth in All Text near/5 crown* in All Text) or (teeth in All Text near/5 crown* in All Text) or (dental in All Text near/5 coronal* in All Text) or (tooth in All Text near/5 coronal* in All Text) or (teeth in All Text near/5 coronal* in All Text))
#12 MeSH descriptor Denture, partial explode all trees
#13 MeSH descriptor Dental veneers explode all trees
#14 ((dental in All Text or tooth in All Text or teeth in All Text) and (bridge* in All Text or veneer* in All Text or pontic* in All Text or laminate* in All Text))

#15 (partial in All Text near/5 denture* in All Text)
#16 (#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15)
#17 MeSH descriptor Rubber dams this term only
#18 ((rubber in All Text near/6 dam* in All Text) or (oral in All Text near/6 dam* in All Text) or (dental in All Text near/6 dam* in All Text) or (latex in All Text near/6 dam* in All Text) or Kofferdam in All Text)
#19 ("Optra Dam" in All Text or "OptraDam Plus" in All Text or OptiDam in All Text or FlexiDam in All Text or "Hygenic Fiesta" in All Text)
#20 (#17 or #18 or #19)
#21 (#16 and #20)

Appendix 3. MEDLINE Ovid search strategy

1. exp Dental restoration, permanent/
2. exp Dental restoration, temporary/
3. ((dental or tooth or teeth) adj5 (restor$ or fill$)).ti,ab.
4. Dental atraumatic restorative treatment/
5. ((dental or tooth or teeth) and ("atraumatic restorative treatment" or ART)).ti,ab.
6. Dental amalgam/
7. Glass ionomer cements/
8. ((dental or tooth or teeth) and (restor$ and (inlay or in-lay or onlay or on-lay or post$ or dowel$ or pin$))).mp.
9. ((dental or tooth or teeth) adj5 (amalgam$ or resin$ or cement$ or ionomer$ or compomer$ or composite$)).mp.
10. exp Crowns/
11. ((dental or tooth or teeth) adj5 (crown$ or coronal$)).ti,ab.
12. exp Denture, Partial/
13. exp Dental veneers/
14. ((dental or tooth or teeth) adj5 (bridge$ or veneer$ or pontic$ or laminate$)).mp.
15. (partial adj5 denture$).mp.
16. or/1-15
17. Rubber dams/
18. ((rubber adj dam$) or (oral adj dam$) or (dental adj dam$) or (latex adj dam$) or Kofferdam).mp.
19. ("Optra Dam" or "OptraDam Plus" or OptiDam or FlexiDam or "Hygenic Fiesta").mp.
20. or/17-19

Appendix 4. Embase Ovid search strategy

1. exp Reparative dentistry/
2. ((dental or tooth or teeth) adj5 (restor$ or fill$)).ti,ab.
3. ((dental or tooth or teeth) and ("atraumatic restorative treatment" or ART)).ti,ab.
4. Dental alloy/
5. Glass ionomer/
6. ((dental or tooth or teeth) and (restor$ and (inlay or in-lay or onlay or on-lay or post$ or dowel$ or pin$))).mp.
7. ((dental or tooth or teeth) adj5 (amalgam$ or resin$ or cement$ or ionomer$ or compomer$ or composite$)).mp.
8. exp Crowns/
9. ((dental or tooth or teeth) adj5 (crown$ or coronal$)).ti,ab.
10. exp Denture
11. ((dental or tooth or teeth) adj5 (bridge$ or veneer$ or pontic$ or laminate$)).mp.
12. (partial adj5 denture$).mp.
13. or/1-12
14. ((rubber adj dam$) or (oral adj dam$) or (dental adj dam$) or (latex adj dam$) or Kofferdam).mp.
15. ("Optra Dam" or "OptraDam Plus" or OptiDam or FlexiDam or "Hygenic Fiesta").mp.
16. 14 or 15
17. 13 and 16

Appendix 5. LILACS BIREME Virtual Health Library search strategy

(dental or dentária or tooth or teeth or dente$ or diente$) [Words] and (Mh Rubber dams or "rubber dam$" or "dique$ de goma" or "dique$ de borracha" or "dental dam$" or "latex dam$" or "oral dam$" or Kofferdam or "Optra Dam" or "OptraDam Plus" or OptiDam or FlexiDam or "Hygenic Fiesta") [Words]

Appendix 6. SciELO BIREME Virtual Health Library search strategy

rubber dam

Appendix 7. CBM search strategy

1. Mesh: rubber dam
2. Key word: rubber dam
3. #2 or #1

This search strategy was translated from Chinese.

Appendix 8. VIP search strategy

rubber dam
This search strategy was translated from Chinese.

Appendix 9. CNKI search strategy

rubber dam
This search strategy was translated from Chinese.

Appendix 10. US National Institutes of Health Ongoing Trials Register (ClinicalTrials.gov) and the WHO International Clinical Trials Registry Platform search strategy

rubber dam

Appendix 11. OpenGrey search strategy

rubber dam

Appendix 12. Sciencepaper search strategy

rubber dam
This search strategy was translated from Chinese.

CONTRIBUTIONS OF AUTHORS

Screening the search results and retrieving the papers: Yan Wang (YW), He Yuan (HY).

Data extraction and risk of bias assessment: YW, HY and Chunjie Li (CL).

Analysing the data and interpreting the results: CL, YW and May CM Wong (MW).

Writing the results, discussion, conclusions and abstract: YW, CL, HY and MW.

Providing a clinical perspective: Xuedong Zhou (XZ), Jing Zou (JZ) and Zongdao Shi (ZS).

YW, CL, and HY contributed equally to producing this systematic review.

DECLARATIONS OF INTEREST

Yan Wang: none known.

Chunjie Li: none known.

He Yuan: none known.

May CM Wong: none known. May CM Wong is an editor with Cochrane Oral Health.

Jing Zou: none known.

Zongdao Shi: none known.

Xuedong Zhou: none known.

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- West China Hospital of Stomatology, Sichuan University, China.
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- UK Cochrane Centre, UK.
- Cochrane Oral Health, UK.
- Cochrane Oral Health Global Alliance, Other.

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- National Institute for Health Research (NIHR), UK.

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DIFFERENCES BETWEEN PROTOCOL AND REVIEW

Added participant acceptance/satisfaction as a secondary outcome.

Used risk ratio as a measure of the survival/success rate of the restorative treatment.

Specified types of subgroup analyses intended to perform.

Rubber Dam: Single Tooth Isolation In Endodontics

by Dr Steven A Cohn

Introduction

These notes should be read in conjunction with the video produced by the Australian Dental Association (NSW Branch) Centre for Professional Development entitled "Rubber Dam: Single Tooth Isolation in Endodontics".

Rubber dam is not new; it was first described in the United States in 1864. Clamp patterns numbers 26 and 27 were introduced in 1870, and the Ainsworth rubber dam punch in 1879. In 1998 the Victorian Dental Board made the use of rubber dam <u>mandatory</u> for routine endodontic treatment. Other states and territories have followed suit. There is no defence against a swallowed or inhaled endodontic instrument. Remember, it's safer, easier, quicker and better with rubber dam.

Advantages of Rubber Dam

- Rubber dam creates a clean, dry working field that enhances your efficiency. Single tooth isolation for endodontics is simple and quick. The average time is 30 to 40 seconds.
- Rubber dam provides a safe working environment by excluding bacteria and viruses normally found in the aerosol created by high-speed handpieces.
- Rubber dam creates a barrier for fine instruments and dental materials.
- Rubber dam relaxes the patient. Salivary flow decreases. Many fall asleep under the rubber dam!
- Rubber dam is a practice builder.
- Rubber dam represents the standard of care.

Contraindications

- Minor damage to marginal gingiva and cervical cementum from the clamp (can be avoided).
- Damage to ceramic crowns or facings from the clamp (can be avoided).

Rubber Dam

Rubber dam is made of natural latex. The most common weights are medium (0.020 mm) and heavy (0.025 mm). Heavy weight will give greater gingival retraction, but is harder to apply.

Medium weight rubber dam is recommended for endodontics. The conventional dark, green and blue colours provide good contrast with the tooth. If using transillumination to look for a canal, the dark colour allows more light through than the other colours.

Fresh stock of rubber dam is essential. The shelf life at room temperature is approximately 9 months. Check the manufacturing date on the box. Stretch the rubber dam and check for tearing.

Allergy to latex is an increasing finding. It can result in anyphylactic shock and death!
Non-latex dam is available with the handling characteristics of natural rubber.

Punching Rubber Dam

The **Ivory pattern** punch is recommended. The rubber dam punch must make a clean hole with no ragged edges or tags. There are 5 hole sizes, from 0.5 mm to 2.5 mm. Set the punch on the largest hole.

Punch the hole in the **centre** of the dam. For posterior teeth this allows you the maximum flexibility to move the frame laterally and achieve the best visibility and tissue retraction, as opposed to using a template stamp of the dental arches. Punch another hole near the top edge of the dam to help with the orientation to the frame (this is an optional step).

For mandibular anteriors and some molars, punch the hole off centre so more dam is available over the maxillary teeth when the patient opens (about **2/3 the distance** from the top of the frame).

With posterior teeth, including the **tooth anterior** to the one receiving the treatment can increase your visibility and ease of access. This is especially relevant when the treated tooth is mesially inclined. To do this, punch a single hole but stretch it over the both teeth. Otherwise, treat as two adjacent teeth.

Fig 1. The rubber dam applied to two adjacent teeth retained by a #26 clamp and Wedjets.

If treating **two adjacent teeth,** allow enough space between the holes for the dam to adapt to the interproximal tissues. Punching a smaller hole for the tooth not being held by the clamp will help with retention. The dam can be inverted around this tooth with a gentle stream of air or by "tucking" the dam around the tooth with dental floss. Use a piece of rubber dam, dental floss, a wooden wedge or a section of **Wedjets** material interproximally to further secure it (Fig.1). A small amount of glass ionomer cement on the labial surface will also assist in keeping the dam in place (this is particularly useful in children where only partial eruption has occurred). These methods of retention are helpful when using a **rubber dam "cuff".**

The **rubber dam "cuff"** consists of punching two holes approximately half to two thirds the distance to be stretched, cutting a slit between them with a scissors, and stretching the dam over the tooth you are treating and at least one tooth to either side. Punching the holes at either end prevents the dam from tearing when it is stretched in this way.

The cuff is very useful for treating traumatized teeth, partially erupted maxillary incisors in children or where a crown lengthening procedure for clamp retention would cause aesthetic problems (Fig 2). A cotton roll in the labial sulcus will help to control any saliva.

Fig. 2 The rubber dam cuff is ideal for the isolation of a traumatized tooth.

In posterior teeth that require pretreatment (excavation and/or banding), the cuff should be used if there is a tooth posterior to the one needing treatment that can be clamped. This will provide a dry field and tissue protection. Secure the dam interproximally on the anterior tooth with a piece of rubber dam, dental floss, a wooden wedge or a section of Wedjets (Fig 3).

Fig 3. The rubber dam cuff applied for the excavation of tooth 1.6

The rubber dam cuff is very useful when restoring teeth with moisture sensitive materials. It is an easy way to introduce the rubber dam for routine restorative dentistry.

Oraseal, a silicone based material, can be applied to exposed gingival tissues to further control leakage (Fig 4).

NB: Rubber dam cuffs and other clampless techniques are radiolucent on a radiograph. For medico-legal reasons, write in your treatment notes that the cuff was used.

Fig 4. Oraseal provides an excellent seal around the rubber dam

Clamp Forceps
The **Stokes pattern** is recommended. The clamp should be engaged by the notches on the beaks. Check the notches for wear. They can be regrooved.

Clamp Selection
Clamps are divided into 2 groups. **Bland** clamps have flat beaks or jaws that point towards one another. **Retentive** clamps have jaws that are directed gingivally. Both groups are further divided into **wingless** and **winged patterns**. Wingless clamp numbers are always preceeded by a "W" (W1, W8A, etc.).

Wingless clamps are probably the easiest to apply when you are 'relearning' use of rubber dam.

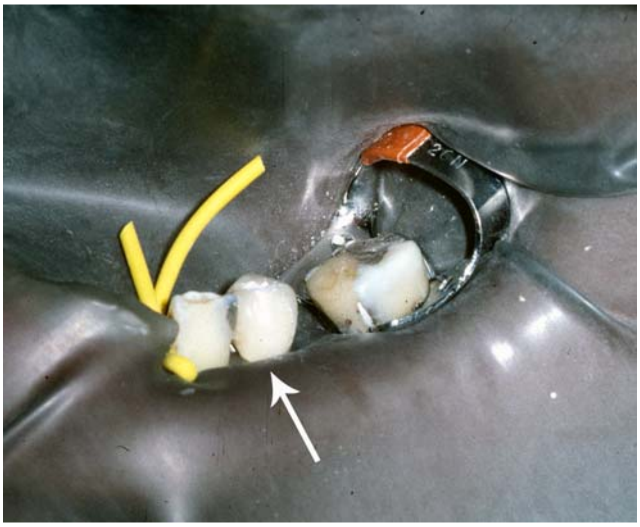
90% of routine cases can be treated with just **4 clamps**. The pattern numbers are made by many companies

- Anteriors: # 9
- Premolars: # W1 or W2A
- Molars: # 26 and W8A (both wingless)

Other very useful clamps include:

- Anteriors: # 211 and W00
- Premolars: # 27 and W1A (both wingless)
- Molars: # W14 and W14A

The # 9 is very useful for any crown prepared tooth with resultant divergent walls. There are many other clamps. The W2, W7 and 13A are also recommended.



Clamps, especially with serrated jaws (W7, etc) provide excellent retention but can damage ceramic crowns or facings.

If there is a risk of such damage, clamp the tooth behind and use Wedjets to secure the dam around the tooth you are treating, or apply a rubber dam cuff (Fig 5).

Fig 5. The rubber dam applied to avoid clamp damage to tooth 3.5 (arrow)

Winged clamps allow good retraction of the dam, but can be difficult to use in certain situations. The wings may obscure the pulp chamber when looking for calcified canals. They also bother some patients with very muscular or active tongues and can make the placement of the X-ray film more difficult.

A clamp may be customised by heating and bending the jaws or grinding off the wings.

More About Clamps
A clamp should always have **4 point contact** gingival to the height of contour for maximum stability. If in doubt, try the clamp first without the rubber dam and **test the stability with your fingers.**

- With anteriors the clamp should resist rotational movement.
- With posteriors the beaks should be parallel to the occlusal plane and the clamp bow should resist vertical movement.

When a clamp is seated below the height of contour and at the gingival margin, the root contours or prominences can be observed. This assists in preparing the correct access cavity.

Try and avoid clamping the gingival tissue. However, on occasion this is unavoidable and causes no permanent damage. It is preferable to do an apically repositioned flap or a simple electrosurgery procedure first. **Local anaesthetic** may be necessary prior to clamp placement in these situations.

Whatever technique you use to place the dam, stabilise the clamp with your fingers when releasing the forceps to make sure it does not slip off and damage the tooth surface or gingival tissue.

If the clamp will not hold to a surface, create a height of contour with glass ionomer or composite resin coronal to where the clamp beak should sit.

With anterior teeth, the lip can often be pinched by the bow of a 9 or 211 clamp. Check the tissue before placing the rubber dam frame. With posterior teeth, the same is true as pinching may occur at the corner of the mouth.

Floss the proximal contacts after the clamp and dam are in position. Check for leakage of saliva. Posterior clamps with tapering beaks (W7, etc.) often allow the dam to slip off at the mesio-buccal and/or mesio-lingual, particularly if there is any tension on the dam. Select another clamp on these occasions with beaks of uniform thickness, such as the # 26. If leakage is present, use a sealant such as Oraseal.

With posterior teeth, you may decide to put the clamp on first. Light lubrication of the dam with liquid soap or topical anaesthetic will facilitate slipping it over the clamp.

Rubber Dam Frame
The **Ostby** plastic frame is recommended because it assists when taking radiographs with the rubber dam on. It also helps in retracting the cheek and lips for better visibility with posterior teeth. However, the Star Visiframe and Young's frame may also be used. The latter is metal

and may be superimposed on the X-ray film. Neither provide quite as much visibility as the Ostby frame when treating posterior teeth.

Keep the points on the Ostby frame sharp with a scalpel or disk so that the dam engages it without slipping.

Before placing the Dam
Floss the proximal contacts before applying the dam. If necessary open the contacts with a separating strip of choice - the Horico serrated steel strips (size 416 or 418) are recommended. Smooth the proximal surface with an abrasive strip.

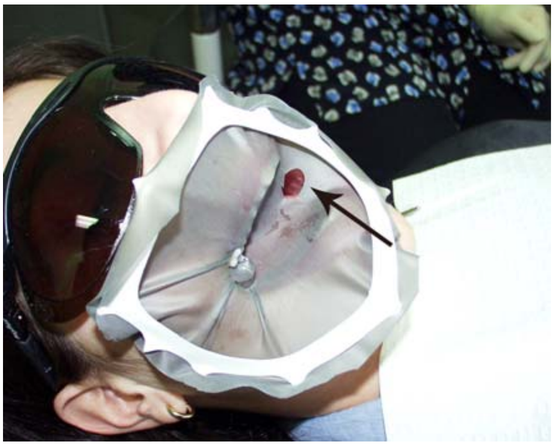
Posterior teeth may require placement of an **orthodontic band** to prevent leakage between appointments. A band will also assist with clamp stability (Fig 6).

Fig 6 An orthodontic band both protects the tooth and assists rubber dam placement.

Local Anaesthetic may be required because the clamp can be painful if it is against gingival tissue or cementum. Pay particular attention to the palatal tissues of premolars and molars.

If the patient's lips are dry, **lubricate** the corners of the mouth before placing the dam.

When the Dam is on
Patient comfort can be increased by using a **rubber dam napkin** under the dam. "Chux" towelling, facial tissues or gauze squares may also be used.



Some patients may feel the rubber dam restricts their breathing. Either **offset** the dam on the frame to create a breathing space, or make a **small hole** in the dam with scissors well away from the tooth being treated (Fig 7).

Fig 7. Breathing can be assisted by cutting a small hole in the dam (arrow) away from the tooth being treated

Patients can swallow normally with the rubber dam. **Routine use of a saliva ejector is not necessary!** Patients relax under the rubber dam and salivary flow decreases. For those few who require suction, your chairside assistant can do this periodically. Suction should be considered when adjusting the rubber dam prior to taking a radiograph and just before removal of the rubber dam.

If your patient complains of a **bad taste**, sodium hypochlorite is leaking either around the dam or via the access cavity. If you suspect access cavity leakage, fill the access cavity with water and observe if the level stays the same (no leak) or changes. If you are still not sure, suction around the periphery of the tooth while observing the water level.

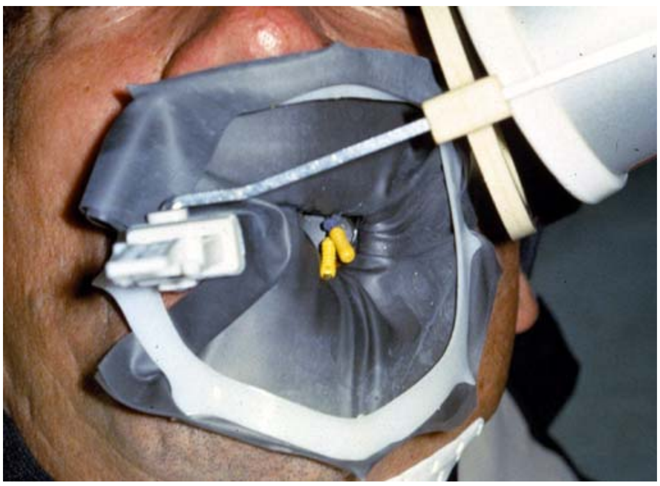
Leakage must be prevented by carrying out pretreatment procedures (excavate, seal, possibly band or place a temporary crown). Leakage can be sealed temporarily from within the access cavity to allow the completion of that particular visit. However, the restoration should be replaced before continuing the endodontic treatment.

If a slow speed round bur gets caught in the dam, operate your handpiece **in reverse** to free it; the dam is rarely torn when this is done.

Repairs to Rubber Dam
Should the dam develop a small tear during treatment from a bur, etc, it may be possible to repair this with Oraseal. Another method is to put some **impression tray adhesive** over the hole and glue a little piece of dam over the tear. If the tear is interproximal, check for a rough proximal edge or surface and smooth it before you apply the dam the next time.

On posterior teeth a **second rubber dam** can be applied over the torn one and held in position with a second frame (Fig 8). If you have any doubts about further leakage, replace the dam!

Fig 8 Example of a second dam and frame applied to control leakage



Radiographs with Rubber Dam
It is not necessary to remove the rubber dam if special **film positioning devices** such as the Snapex are used (Fig 9).

Fig 9 The rubber dam is compatible with the Snapex radiographic system

Fig 10. Removal of the rubber dam clamp for radiographs can assist in locating calcified canals

If a clamp is obscuring a calcified pulp chamber or canal, place **Wedjets interproximally** and remove the clamp to take the film (Fig. 10)

Removing Rubber Dam
To remove the dam, stabilise the clamp with the fingers and squeeze the forceps sufficiently to stretch the clamp so it clears the heights of contour on the buccal and lingual **before** you remove it.

Inspect the hole in the dam for any missing rubber that may have torn off and remained wedged interproximally. Floss the contact points to remove any such remnants.

If you used Oraseal or Cavit, etc, to seal any leaks, check that you have removed any residual material from around the tooth.

Summary
The rubber dam improves clinical treatment and provides protection for both the patient and yourself. The aim of the video and these notes is to increase your expertise in the use of the rubber dam for endodontic procedures.

Any suggestions for improving this material would be most welcome. Thank you for watching the video and reading these notes.