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REVIEW

Rubber dam usage for endodontic treatment: a review

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Abstract

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Rubber dam has been available to the dental profession for over 140 years. During this time, the use of rubber dam has been perfected, universally taught and recommended by professional organizations. Unfortunately, its consistent use has been rejected by many in the profession. The literature suggests that rubber dam is not used routinely by dental practitioners for root canal treatment. Many unfounded reasons have been cited for its lack of use, including concerns over patient acceptance, time required for application, cost of equipment and materials, insufficient training, difficulty in use and low treatment fees. Failure to use rubber dam has been shown to influence the choice of root canal irrigant, has a negative impact on treatment outcome and places the patient at risk of swallowing or aspirating materials and instruments. Methods to popularize rubber dam amongst general practitioners are discussed.

Keywords: disincentives, prevalence, rubber dam, survey, treatment outcome.

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Introduction

The rubber dam was introduced to the dental profession by Dr Sanford C. Barnum on 15 March 1864 (Elderton 1971). Since then, a number of publications have appeared related to its practicality and methods of application (Elderton 1971, Cragg 1972, Antrim 1983, Reuter 1983, Carrotte 2000, 2004, Ingle *et al.* 2002, Glickman & Pettiette 2006, Bhuva *et al.* 2008).

The use of the rubber dam during root canal treatment confers three main advantages: control of cross-infection, protection and improving treatment efficiency.

The use of the air turbine results in the formation of aerosols and droplets that are usually contaminated with bacteria and blood. These aerosols and droplets represent a potential route for transmission of infectious diseases such as measles, tuberculosis, SARS, hepatitis and AIDS (Wong 1988, Forrest & Perez 1989, Harrel & Molinari 2004). The use of rubber dam results in a significant reduction in the microbial content of air turbine aerosols produced during operative procedures, thereby reducing the risk of cross-infection in the dental practice (Wong 1988, Cochran *et al.* 1989, Forrest & Perez 1989, Samaranayake *et al.* 1989, Harrel & Molinari 2004).

Rubber dam protects the patient's oropharynx from the possible aspiration or swallowing of instruments, medicaments, irrigating solutions and tooth/material debris (Ingle *et al.* 2002, Glickman & Pettiette 2006) and subsequently the operator from legal responsibility should these accidents occur (Cohen & Schwartz 1987, Cohen 1989, Peters & Peters 2007). It also retracts and protects the soft tissues (gingival tissues, tongue, lips and cheeks) from rotary and hand instruments, medicaments and potential the trauma of repeated manual manipulation (Ingle *et al.* 2002, Glickman & Pettiette 2006).

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Furthermore, rubber dam enhances treatment efficiency by:

- Improving the access to operating field by retraction of soft tissues.
- Improving visibility by providing a dry field, reducing mirror fogging and enhancing visual contrast.
- Facilitating the practice of four-handed dentistry during endodontic treatment. Instead of having to be careful about protecting the patient's airways, controlling and retracting the soft tissues, both the operator and the dental nurse can concentrate on the endodontic procedure.
- Reducing flooding of the oral cavity with fluids, especially those with unpleasant taste [i.e. sodium hypochlorite (NaOCl)]. This eliminates the need for repeated change of cotton rolls and frequent rinsing by the patient.
- Minimizing patients' conversation during treatment and encouraging them to maintain their mouths open.

(Ingle *et al.* 2002, Glickman & Pettiette 2006, Bhuva *et al.* 2008)

These advantages have led to the use of rubber dam being accepted as a standard of care by professional organizations (European Society of Endodontology 1992, 2006, American Association of Endodontists 2004, American Academy of Pediatric Dentistry 2008–2009). In addition, the use of rubber dam is taught and required in most dental schools (Smith & Richeson 1981, Petersson *et al.* 2002). Yet, in spite of these advantages and recommendations, the use of rubber dam is frequently ignored by practicing dentists. Ireland (1962) summed up this poor acceptance rate of rubber dam by saying: 'Probably no other technique, treatment or instrument used in dentistry is so universally accepted and advocated by the recognized authorities and so ignored by the practicing dentists'. Unfortunately, this statement is as appropriate today as it was at that time.

The purpose of this paper is to review the different aspects of rubber dam use in root canal treatment and discuss the possibilities to popularize its use amongst dental practitioners. A literature search was conducted by the author using the PubMed database. The search keywords and the results of this search are shown in Table 1. After removing repeat articles, an initial list of 146 articles was obtained. The author then screened the title and abstract of each article in this list and included only those which contained data regarding one or more of the following aspects: prevalence of rubber dam use, disincentives of its regular use and clinical considerations associated with its use in endodontic treatment. Title/abstract screening identified 48 relevant articles. These articles were retrieved in full text and the reference lists from each of them were manually checked for additional articles of relevance.

Table 1 The keywords searched on PubMed and the number of publications found

Number	Keywords	Result (articles)
1	Rubber dam and endodontic	86
2	Rubber dam and prevalence	10
3	Rubber dam and disincentive	1
4	Rubber dam and accident	12
5	Swallowing and endodontic	13
6	Aspiration and endodontic	24
7	Rubber dam and litigation	9
8	Rubber dam and treatment outcome	23
	Relevant articles remaining after removing repeat articles	146
	Relevant articles remaining after title/abstract screening	48

Prevalence of rubber dam use

Surveys undertaken in several countries reported various rates of rubber dam usage when performing endodontic treatment (Table 2). There is a discrepancy between the frequency of rubber dam use between undergraduate students and practicing dentists. Silversin *et al.* (1975) reported a usage rate exceeding 90% of cases requiring root canal treatment amongst 92.4% of undergraduate students, 13.6% of private practitioners and 3.4% of National Health Service practitioners in the UK. In another study, the students were asked to predict their future use of rubber dam for a number of dental procedures (Ryan & O'Connell 2007). All the students predicted that following graduation they would use the rubber dam when performing endodontic therapy for an adult and 98.5% of them would use it for pulp therapy on a child. Similarly, 98% of final-year students in two dental schools in Wales and Ireland reported that they would continue to place rubber dam during performing root canal treatments as they settle in their practices (Mala *et al.* 2009). On the contrary, rubber dam use tends to dramatically decrease following graduation and root canal treatment in general dental practice is usually performed without it (Table 2).

Many factors have been suggested to influence the frequency of rubber dam usage (Table 3). The reported usage appears to be unrelated to operator gender (Marshall & Page 1990, Palmer *et al.* 2009), postgraduate training (Hagge *et al.* 1984, Joynt *et al.*

Table 2 Prevalence of rubber dam use for endodontic treatment

Study	Country	Operator	Prevalence of rubber dam use (%)
Going & Sawinski (1967)	USA	Dentist	Always (6.6%), mostly (39.6%), occasionally (16.8%), seldom (13.4%), never (23.5%)
Silversin *et al.* (1975)	UK	UGS	Always (57%), generally (35.4%), frequently (4.3%), sometimes (3.3%)
		GDP/NHS	Always (1.5%), generally (1.9%), frequently (1.9%), sometimes (4.3%), rarely (15.1%), never (73.9%)
		GDP/PP	Always (6.8%), generally (6.8%), frequently (6.8%), sometimes (10.7%), rarely (19.4%), never (40.8%)
Tidmarsh (1980) (Cited in Koshy & Chandler 2002)	New Zealand	GDP	Always (4%), usually (10%), occasionally (30%), never (52%)
British Endodontic Society (1983)	UK	GDP/NHS	Routine use (5%)
		BES/NHS	Routine use (35%)
		GDP/PP	Routine use (58%)
		GDP/SE	Routine use (44%)
Swallow (1983)	UK	GDP	7.57% used rubber dam 1 month ago 5.12% used rubber dam in the last year 88.84% used the rubber dam more than a year or never used it
Hagge *et al.* (1984)	USA	USAFGD	81–100% of time (97.7%), 61–80% of time (1%), 41–60% of time (0.4%), 21–40% of time (0.2%), 0–20% of time (0.7%)
Joynt *et al.* (1989)	USA	Dentist	Always (62.1%), never (11%)
Marshall & Page (1990)	UK	Dentist	Most or always (10.9%), occasionally (7.4%), never or seldom (81.7%)
Brookman (1991)	UK	DVT	Routinely (31%)
Whitten *et al.* (1996)	USA	GDP	Always (59%)
		Endodontist	Always (92%)
Barbakow (1996)	Switzerland	Dentist	Regularly (31%)
Saunders *et al.* (1999)	Scotland	GDP	Routinely (24.9%)
Whitworth *et al.* (2000)	UK	GDP/NHS	Always/frequently (20.3%), never (58.1%)
Ahmed *et al.* (2000)	Sudan	GDP	Yes (2%), no (98%)
Jenkins *et al.* (2001)	UK	Dentist	Routinely (19%), never (44.5%)
Stewardson (2001)	UK	GDP/NHS	Always (3.07%), more often than not (7.98%), occasionally (25.77%), never (63.18%)
		GDP/PP	Always (28%), More often than not (8%), Occasionally (40%), Never (24%)
Stewardson (2002)	UK	GDP	Always (20.6%), more than no (20.4%), occasionally (37.4%), never (21.6%)
Koshy & Chandler (2002)	New Zealand	GDP	Routinely (58%)
Slaus & Bottenberg (2002)	Belgium	Dentist	Always (3.4%), sometimes (18.5%), never (77.3%)
Hommez *et al.* (2003)	Belgium	Dentist	Always (7.2%), limited cases (20.5%), never or seldom (64.5%)
Al-Omari (2004)	Jordan	GDP	Occasionally (3.8%)
Wilson *et al.* (2004)	UK	GDP	61% did not use rubber dam for endodontics, let alone any other procedure
Bjørndal & Reit (2005)	Denmark	GDP/PP	Often (4%), occasionally (14%)
Lynch & McConnell (2007)	Ireland	GDP	Anteriors: always (27%), mostly (9%), often (6%), occasionally (2%), rarely (17%), never (39%) Premolars: always (32%), mostly (14%), often (2%), occasionally (6%), rarely (14%), never (32%) Molars: always (40%), mostly (9%), often (6%), occasionally (7%), rarely (12%), never (26%)
Hill & Rubel (2008)	USA	GDP	Always (58%), never (11%)
Koch *et al.* (2009)	Sweden	GDP	Always (67%), routinely (20%)
Palmer *et al.* (2009)	UK	Dentist	All cases (30.3%), some cases (37.4%)

Table 2 (*Continued*)

Study	Country	Operator	Prevalence of rubber dam use (%)
Mala *et al.* (2009)	UK and Ireland	UGS	Anteriors: always (87.4%), mostly (8%), often (1.1%), occasionally (1.1%), rarely (0%), never (2.3%) Premolars: always (90.8%), mostly (5.7%), often (0%), occasionally (1.1%), rarely (0%), never (2.3%) Molars: always (87.4%), mostly (6.9%), often (0%), occasionally (1.1%), rarely (2.3%), never (2.3%)

UGS, undergraduate student; GDP/NHS, general dental practitioner working under UK National Health Service regulations; BES/NHS, British Endodontic Society members working under UK National Health Service regulations; GDP/PP, general dental practitioner working in private practice; GDP/SE, general dental practitioner with salaried employment; USAFGD, US Air Force general dentist; DVT, dentist in vocational training.

Table 3 Factors affecting frequency of rubber dam use

Reference	Factor (statistical result)
Swallow (1983)	Time since graduation (NS)
Hagge *et al.* (1984)	Qualifying year (NS) Residency training (NS)
Joynt *et al.* (1989)	Undergraduate training (S; usage increased with extensive training) Postgraduate training (NS) Position in practice (S; group practice > solo practice)
Marshall & Page (1990)	Qualifying school (NS) Qualifying year (NS) Operator gender (NS) Practice location (NS) Practice type (S; private > mixed > NHS)
Saunders *et al.* (1999)	Time since graduation (NS)
Whitworth *et al.* (2000)	Qualifying school (S) Qualifying year (NS)
Jenkins *et al.* (2001)	Operator age (NS) Number of root canal fillings completed per month (NS)
Stewardson (2002)	Qualifying school (NS) Qualifying year (NS)
Koshy & Chandler (2002)	Qualifying school (NS) Position in practice (S; group practice > solo practice) Interest in endodontics (S; highly interested operators used it more)
Hommez *et al.* (2003)	Time since graduation (NS)
Al-Omari (2004)	Professional experience (NS)
Wilson *et al.* (2004)	Practice location (S; Scotland > North West of England)
Palmer *et al.* (2009)	Qualifying school (NS) Operator gender (NS) Operator age (NS)
Mala *et al.* (2009)	Treated tooth (NS) Qualifying school (NS)

S, significant; NS, not significant; NHS, National Health Service.

1989), treated tooth (Mala *et al.* 2009) and number of root canal fillings completed per month (Jenkins *et al.* 2001). There was also no relationship between year of qualification/operator age and frequency of rubber dam use (Swallow 1983, Hagge *et al.* 1984, Marshall & Page 1990, Saunders *et al.* 1999, Jenkins *et al.* 2001, Stewardson 2002, Hommez *et al.* 2003, Al-Omari 2004, Palmer *et al.* 2009) indicating that its use in daily practice is abandoned quickly following graduation. Some authors (Whitworth *et al.* 2000) found a significant difference in rubber dam use between graduates of different schools, whilst others (Marshall & Page 1990, Koshy & Chandler 2002, Stewardson 2002, Mala *et al.* 2009, Palmer *et al.* 2009) reported no influence of qualifying school on frequency of use. The findings regarding the influence of practice location on rubber dam use were equivocal; no relationship was reported by Marshall & Page 1990, whilst Wilson *et al.* (2004) found that operators in Scotland used rubber dam significantly more frequently than their counterparts in the North West of England. On the contrary, a significantly greater usage rate was reported amongst operators in private practices than those in general practices (Marshall & Page 1990), amongst operators in group practice than those in solo practice (Joynt *et al.* 1989, Koshy & Chandler 2002), amongst practitioners who had an extensive undergraduate training on rubber dam use (Joynt *et al.* 1989) and a high interest in endodontics (Koshy & Chandler 2002).

Disincentives to regular usage of rubber dam

Previous studies have cited a variety of reasons for lack of regular use of rubber dam amongst the dental profession. The most commonly reported reasons include lack of patient acceptance, time required for application, insufficient training, difficulty in use, cost of equipment and materials and low treatment fees (Going & Sawinski 1967, Marshall & Page 1990, Brookman 1991, Saunders *et al.* 1999, Ahmed *et al.* 2000, Whitworth *et al.* 2000, Koshy & Chandler 2002, Stewardson

Table 4 Secondary disincentives of rubber dam use

Inconvenience
Rubber dam is unnecessary
Not used since dental school
Managed without for 30 years
Instruments held in headpieces are being used
Lack of practice and habit and laziness
Lack of confidence in rubber dam use
Difficulty of taking radiographs
Staff unfamiliar with its use
Difficulty in swallowing
Managed without for long period of time
My DSA needs training
Restriction of communication with patient
No one else recommends it in the practice

2002, Lynch & McConnell 2007, Hill & Rubel 2008). Other less common reasons are listed in Table 4.

Many practitioners believe subjectively that patients do not like the rubber dam (Going & Sawinski 1967, Marshall & Page 1990, Brookman 1991, Saunders *et al.* 1999, Whitworth *et al.* 2000, Koshy & Chandler 2002, Stewardson 2002, Lynch & McConnell 2007, Hill & Rubel 2008), which is contrary to the available evidence. Reuter (1983) afforded anecdotal evidence that, based on extensive personal experience, his patients preferred the use of rubber dam for restorative procedures. In addition, a number of questionnaire-based studies surveyed the patients' judgement of their experience of treatment under the rubber dam and their preference for its use in the future (Nelson 1979, Jones & Reid 1988, Gergely 1989, Stewardson & McHugh 2002, Filipović *et al.* 2004, Görduysus 2006). The results (Table 5) showed that the patients are generally not adverse to the use of rubber dam during treatment and that many expressed preference to have it used again in a future visit. A number of factors were suggested and investigated to explore their influence on patient's attitude towards rubber dam application in a current and a future appointment. These factors may be divided into:

- Personal factors relate to patient age and gender; previous rubber dam experience and current rubber dam experience.
- Clinical factors relate to experience, enthusiasm and competency of operator and assistant; time taken to apply rubber dam; duration of rubber dam use; explanation to the patient; number of isolated teeth; use of rubber dam clamp or ligature; use of local anaesthesia; difficulty of rubber dam placement and patient selection.

(Nelson 1979, Jones & Reid 1988, Gergely 1989, Stewardson & McHugh 2002, Filipović *et al.* 2004, Görduysus 2006)

Of these factors, the operator's positive attitude (Gergely 1989) and enhanced experience (Stewardson & McHugh 2002, Filipović *et al.* 2004, Görduysus 2006) have been shown to play the major role in increasing the level of rubber dam acceptance. Consequently, it is suggested that the best way to improve

Table 5 Patients' judgement of their current experience (CE) and their future preference (FP) for treatment with rubber dam

			CE (%)		FP (%)		
Reference	Operator	Procedure	Positive	Negative	Yes	No preference	No
Nelson (1979)	Dentist	DP	–	–	85	–	15
Jones & Reid (1988)	UGS	OP, Endo, Bleaching	Most patients reported low anxiety level		30	49	21
Gergely (1989)[a]	GDP	Endo, Rest, FS	The ratio of favourable to unfavourable comments was 8 : 3		72.2 (73.8)	19.4 (19.1)	8.3 (7.1)
Stewardson & McHugh (2002)[b]	UGS	Endo, Rest, BC	58 (55.9)	42 (44.1)	43 (47.1)	44 (41.2)	13 (11.8)
	GDP	Endo, Rest	78 (80.6)	22 (19.4)	70 (72.2)	26 (22.2)	4 (5.6)
Filipović *et al.* (2004)	UGS	Endo	58.2	41.8	63	37	0
	Specialist	Endo			76	12	12
Görduysus (2006)	UGS	Endo	47.2	52.8	46.2	23.6	30.2
	PGS	Endo	67.4	32.6	77.2	4.3	18.5

GDP, general dental practitioner; UGS, undergraduate student; PGS, postgraduate student; DP, dental procedures; OP, operative procedures; Endo, endodontic treatment; Rest, restorations; FS, fissure sealant; BC, bridge cementation.
[a]Figures shown in the parentheses represent the opinion of the patients who received endodontic treatment only.
[b]Figures shown in the parentheses represent the opinion of the patients who received endodontic treatment only. The data was kindly provided by Dr Dominic Stewardson (personal communication, November 2008).

Table 6 Time required for application of rubber dam

Reference	Operator	Application time (min)	
		Average	Range
Reuter (1983)	Specialist	Requires only a minute or so to prepare and place	
Jones & Reid (1988)	Undergraduate student	5.80	1–20
Gergely (1989)	Dentist	1.90	<1 to >5
Baltadjian & Mahseredjian (1992)	Undergraduate student	5.07	1.80–11.53
Stewardson & McHugh (2002)	Dentist	1.27	0.25–8
	Undergraduate student	4.65	1–30
Filipović *et al.* (2004)	Specialist and resident	1.70	0.5–15
	Undergraduate student	4.40	
Görduysus (2006)	Undergraduate student	3.77 (1.89)[a]	
	Postgraduate student	2.39 (1.56)[a]	
Ryan & O'Connell (2007)	Undergraduate student	5.00 (Adult patients)	
	Undergraduate student	8.00 (Children patients)	

[a]Figures shown in the parentheses represent the standard deviation (SD).

patient acceptance is for the operator to use the rubber dam frequently and thereby become proficient (Stewardson & McHugh 2002). This confirms earlier findings of Wolcott & Goodman (1965) who reported that frequent rubber dam users encountered fewer patient objections and came to the conclusion that either the dentists' motivation to use rubber dam may be reflected by the presentation of rubber dam to patients or dentists may rationalize their failure to use rubber dam by claiming patient resistance.

Another quoted obstacle to use of rubber dam is the additional time taken to place it (Going & Sawinski 1967, Marshall & Page 1990, Brookman 1991, Saunders *et al.* 1999, Ahmed *et al.* 2000, Whitworth *et al.* 2000, Koshy & Chandler 2002, Stewardson 2002, Hill & Rubel 2008). Such reluctance appears to be because this time is perceived as wasted time rather than an adjunct to complete treatment (Ryan & O'Connell 2007). However, the literature suggests (Table 6) that rubber dam can be applied, even by an inexperienced operator, in few minutes (Reuter 1983, Jones & Reid 1988, Gergely 1989, Baltadjian & Mahseredjian 1992, Stewardson & McHugh 2002, Filipović *et al.* 2004, Görduysus 2006, Ryan & O'Connell 2007). In addition, this 'relatively slight loss of time' is more than compensated by better working conditions offered by the rubber dam including freedom from the patient's tongue and lips, salivary contamination and eliminating the need for repeated change of cotton rolls and frequent rinsing by the patient (Reuter 1983, Filipović *et al.* 2004).

Some practitioners attribute their low rubber dam use to concerns over their training and the technical difficulties associated with its use (Going & Sawinski 1967, Marshall & Page 1990, Brookman 1991, Whitworth *et al.* 2000, Stewardson 2002, Lynch & McConnell 2007). This claim is not valid as most dental schools teach and require the use of rubber dam during undergraduate training (Smith & Richeson 1981, Petersson *et al.* 2002), a finding that is confirmed by practicing dentists including infrequent users (Silversin *et al.* 1975, Swallow 1983, Stewardson 2002, Lynch & McConnell 2007). The ability to place rubber dam successfully and efficiency comes with experience which, in turn, comes with regular use (Lynch & McConnell 2007, Ryan & O'Connell 2007). Therefore, the limited utilization of this technique may be related to lack of proficiency rather than lack of knowledge or insufficient training (Lynch & McConnell 2007).

The 'cost' and 'low fees for treatment' are traditionally advanced as reasons for infrequent use of rubber dam (Marshall & Page 1990, Ahmed *et al.* 2000, Koshy & Chandler 2002, Stewardson 2002), particularly by dentists working in public sector who feel that its use is not cost-effective in the light of inadequate treatment fees (Saunders *et al.* 1999, Whitworth *et al.* 2000). Nevertheless, the rubber dam armamentarium (i.e. punch, forceps and frame) may serve for a long period of time should they be used properly. In addition, a technique that has a clear infection control benefit and medico-legal and safety implications should not be excluded from use for reasons of cost (Lynch & McConnell 2007). This has been confirmed by a recent report where no respondent referred to cost as a reason for not using rubber dam (Hill & Rubel 2008).

It seems therefore, that the majority of these disincentives are based on unfounded myths rather than evidence-based reasoning. A support for this conclusion comes from the work of Whitworth *et al.* (2000) who compared the perception of frequent and infrequent/nonusers of the commonly reported disincentives to

rubber dam use, namely patient's acceptance, application time, low treatment fees, insufficient training, difficulty in use and cost of materials. The results showed that frequent users were significantly less likely to cite these disincentives (except for the cost of materials) than infrequent/nonusers. Interestingly, the differences were particularly marked for the two reasons that related to the relationship between time and money (low treatment fee and long application time).

Clinical considerations

The use of rubber dam for root canal treatment has several clinical implications on choice of root canal irrigant, patient-safety and treatment outcome.

Root canal irrigants play an integral role in canal preparation procedures and are needed to eliminate microorganisms, dissolve organic debris, flush out debris and lubricate root canal instruments (European Society of Endodontology 2006). Many irrigants are available but NaOCl is considered the main irrigant of choice because of its broad antimicrobial spectrum and unique capacity to dissolve necrotic tissue remnants (Zehnder 2006). However, it is potentially irritant and has an unpleasant taste and odour. Therefore, irrigation with NaOCl should be accompanied by isolation of the operating field with a well-fitting rubber dam. There is evidence suggesting a relationship between rubber dam use and the choice of NaOCl as an irrigant. Frequent rubber dam users were more likely to use NaOCl and in higher concentrations than nonusers/infrequent users who were more likely to use bland solutions such as local anaesthetics (Saunders *et al.* 1999, Whitworth *et al.* 2000, Jenkins *et al.* 2001, Koshy & Chandler 2002, Slaus & Bottenberg 2002, Stewardson 2002). A similar positive relationship was also observed between rubber dam use and irrigation with ethylenediaminetetraacetic acid (EDTA) (Saunders *et al.* 1999, Koshy & Chandler 2002), and use of ultrasonics (Saunders *et al.* 1999). Rubber dam use did not influence the selection of chlorhexidine, saline and hydrogen peroxide as root canal irrigants (Whitworth *et al.* 2000, Koshy & Chandler 2002).

The importance of oral microorganisms in the pathogenesis of apical periodontitis is well established (Kakehashi *et al.* 1965, Fabricius *et al.* 1982). Successful management depends on effective infection control measures to eliminate the existing infection and prevent re-infection of the root canal system. This can be achieved more predictably by isolating the operating field with a well-fitting rubber dam. However, there is a lack of *direct* evidence to demonstrate that using rubber dam improves the outcome of endodontic treatment. Indeed, controlled clinical trials are unavailable because a control group cannot be used, as endodontic treatment cannot ethically be performed without rubber dam. Nevertheless, a negative impact of nonuse of rubber dam on root canal treatment can be *indirectly* inferred (Abbott 1994, Van Nieuwenhuysen *et al.* 1994, Accorinte *et al.* 2006). In a retrospective clinical study, Van Nieuwenhuysen *et al.* 1994 evaluated the influence of a number of technical and clinical factors on outcome of 612 retreatment cases. The results showed that retreatment outcome was significantly better in cases isolated with rubber dam compared with those with cotton rolls. In a later study, Abbott (1994) evaluated 100 referred patients to determine the frequency of various factors associated with continuing pain after the commencement of root canal treatment. The results revealed 23 different factors of which the 'lack of use of rubber dam' ranked first and was observed in 87% of patients. The author recommended adherence to accepted treatment guidelines, including the use of rubber dam, to predictably relieve pain when carrying out emergency endodontics. A recent study investigated the influence of two isolation methods (rubber dam or cotton roll) on the response of the human pulps capped with calcium hydroxide or an adhesive system (Accorinte *et al.* 2006). Direct pulp capping was performed on 40 caries-free human premolars scheduled for orthodontic extraction. After a period of 30 or 60 days, the teeth were extracted and serial histological sections of the teeth were prepared. Although comparable results were recorded for calcium hydroxide capped teeth regardless of the isolation method used, a more severe inflammatory response was seen in the pulps of teeth capped with the bonding system in the absence of rubber dam. The authors attributed this poor result to invasion of bacteria that occurred during the operative procedure that was performed without rubber dam isolation (Accorinte *et al.* 2006).

Despite the scarcity of scientific evidence to demonstrate that rubber dam improves the quality of care, its use during root canal treatment is considered the minimum safety standard of care (Cohen & Schwartz 1987, Cohen 1989, Peters & Peters 2007). The importance of the safety afforded by rubber dam is highlighted by the list of endodontic instruments that have been swallowed (Christen 1967, Goultschin & Heling 1971, Heling & Heling 1977, Taintor & Biesterfeld 1978, Gouila 1979, Lambrainidis & Bettes 1996, Kuo & Chen 2008) or inhaled (Israel & Leban 1984, Debeljak *et al.* 1999) by

patients being treated without rubber dam. Susini *et al.* (2007) examined the records of two insurance companies representing 24 651 French general dentists covering an 11-year-period and found that the incidence of aspiration or ingestion of endodontic instruments was very low (0.001 per 100 000 and 0.12 per 100 000 root canal treatments, respectively). In spite of their low incidence, the occurrence of these mishaps subjects the dentist to litigation. In the USA, these mishaps put the dentist at an indefensible legal position, as there would be no argument regarding liability and that the only real question would be the amount of settlement or the injury award that would be made (Cohen & Schwartz 1987, Cohen 1989). In other countries, such as Germany, clinical guidelines recommend the use of rubber dam for endodontic treatment, but they are not legally binding (Figgener 2007). However, these guidelines may be used by a patient's attorney to pass the 'burden of proof' to the dentist who has to explain why the rubber dam was not used for the treatment (Figgener 2007). Therefore, these mishaps are best avoided by encouraging dental practitioners to use rubber dam for endodontic procedures. Instead of scaring, the dentists of the possibility of incidents when rubber dam is not used, more emphasis should be placed on positive reasons for its use including patient comfort, improved visibility, reduction of the stress from safety concern, time saving, increased medical and hygienic standard of care (Susini *et al.* 2007).

In spite of the ample research about rubber dam, one question remains to be answered: why a universally advocated technique is not practiced by the majority of working dentists? Some investigators demonstrated that many dental techniques taught in the dental school, including rubber dam, are not consistently applied once the graduates settle into practice (Silversin *et al.* 1975, Jenkins *et al.* 2001, Stewardson 2001, Slaus & Bottenberg 2002). This indicates that the discrepancy between the use of rubber dam within and outside the dental school is not because of ineffective training, but as a result of less emphasis on the rationale for using the rubber dam and its relevance in the practice of modern dentistry (Swallow 1983, Joynt *et al.* 1989). Others suggested that the most time-consuming aspect about rubber dam is the time required to convince the dentist to use it (Cragg 1972). Therefore, the routine use of the rubber dam in everyday clinical practice may be encouraged at the undergraduate level by teaching the students effective and simple methods of its placement and at the same time motivating (and later convincing) the students to use it by emphasizing the positive aspects of the technique (i.e. infection control, protection and improving treatment efficiency). Following graduation, continuing education courses, particularly those with a hands-on component, are invaluable to improve and update the practitioners' clinical skills (Saunders *et al.* 1999, Lynch & McConnell 2007). It is hoped that these measures will make rubber dam use an essential dental procedure. At that time, the focus may shift from the frequency of rubber dam use to the quality and effectiveness of the isolation achieved by it (Liebenberg 1995).

Conclusion

In general dental practice, the current use of rubber dam during root canal treatment is low. Many reasons, particularly patient acceptance, time of rubber dam application and cost, are often advanced by dentists as disincentives to rubber dam use. Omission of rubber dam use influences other aspects of endodontic treatment, such as irrigant choice and treatment outcome, and subjects the dentist to litigation if the patient swallows or aspirates endodontic instruments and materials. Besides effective training, routine rubber dam use must be encouraged by convincing the dentist of its value and merits.

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