Endodontics

Restoring teeth that are endodontically treated through existing crowns. Part I: Survey of pulpal status on access



Glenn Trautmann, DMD¹/James L. Gutmann, DDS²/Martha E. Nunn, DDS, PhD³/ David E. Witherspoon, BDSc, MS⁴/Jay D. Shulman, DMD, MA, MSPH⁵

> Objective: The purpose of this study was to identify the pulpal findings encountered by practitioners when accessing complete-coverage crowns that require nonsurgical root canal treatment and the relevance of coronal leakage to the success of the RTC. Method and materials: The survey package consisted of a cover letter stating the instructions, rationale, and purpose for the guestionnaire, a guestionnaire with 8 short-answer questions, and a stamped, self-addressed envelope. A randomized sample of active dentists (300 general practitioners, 300 prosthodontists, and 300 endodontists) was selected. Collected data were analyzed with the chi-square test. Results: A 60% response rate was obtained. Statistically significant differences were found among the practitioner groups, depending on the question, General practitioners and endodontists obtain access through crowns and maintain these crowns as final restoration significantly more often than do prosthodontists. Practitioners responded that teeth with complete crowns require nonsurgical root canal treatment after 5 to 10 years. Conclusion: Respondents believe that leakage must be addressed when endodontic access cavities in artificial crowns are restored after nonsurgical root canal treatment. General practitioners perform nonsurgical root canal treatment more frequently than do prosthodontists. Practitioners indicated that when teeth with complete crowns require nonsurgical root canal treatment, treatment is most often performed 5 to 10 years after placement of the crown (Quintessence Int 2000:31:713-718)

Key words: complete-coverage crown, endodontist, general practitioner, leakage, prosthodontist, root canal treatment, survey

CLINICAL RELEVANCE: This report will help to establish guidelines for an evidence-based study to identify which materials minimize leakage when crowned teeth that require nonsurgical root canal treatment are restored.

- Graduate Resident-Graduate Endodontics, Department of Restorative Sciences, Baylor College of Dentistry, Texas A&M University System, Health Science Center, Dallas, Texas.
- Professor and Director of Graduate Endodontics, Department of Restorative Sciences, Baylor College of Dentistry, Texas A&M University System, Health Science Center, Dallas, Texas.
- Assistant Professor, Department of Public Health Sciences, Baylor College of Dentistry, Texas A&M University System, Health Science Center, Dallas, Texas.
- Assistant Professor-Graduate Endodontics, Department of Restorative Sciences, Baylor College of Dentistry, Texas A&M University System, Health Science Center, Dallas, Texas.
- *Associate Professor, Department of Public Health Sciences, Baylor College of Dentistry, Texas A&M University System, Health Science Center, Dallas, Texas.

Reprint requests: Dr James L. Gutmann, Baylor College of Dentisity, Graduate Endodontics (Room 335), 3302 Gaston Avenue, Dallas, Texas 75246, E-mail:joutmann@tambcd.edu Complete-coverage artificial crowns provide the best treatment option for teeth that have large defective restorations. The crown protects the tooth from further insult and maintains it as a functional, esthetic unit. Some teeth may also receive this treatment to maintain or enhance the health of the periodontum. In spite of these advantages, between 2% and 24% of teeth restored with complete coronal restorations show subsequent signs of pulpal disease or degeneration that requires nonsurgical root canal therapy.¹⁻⁵ Endodontists estimate that 20% to 50% of their cases involve teeth with complete-coverage crowns.⁶

The cumulative insult of periodontal disease and treatment,⁷⁻¹⁰ caries,¹¹⁻¹⁴ and restorative procedures¹⁵⁻¹⁹ often impacts the integrity of the dental pulp. Mechanical cutting of tooth structure with high-speed rotary instruments, the toxic effects of some materials applied to freshly cut dentin, and the adherence of bacterial plaque to dentin surfaces are major factors that result in irreversible inflammatory changes in the pulp.^{1,6,20,21} The additive effect of these results in a tooth with a complete-coverage restoration and seriously compromised pulpal health. Signs and symptoms may or may not be present during this process, even if the pulp has undergone necrosis.²²

Nonsurgical root canal treatment (NSRCT) must be regarded as incomplete until a proper coronal restoration is placed. This restoration is an integral part of establishing a barrier between the periradicular tissue and the oral cavity.23,24 Poor selection of restorative material or lack of a restoration may adversely affect the seal of the root filling, resulting in bacterial contamination of an otherwise favorable root canal treatment.25 The technical quality of a coronal restoration is as significant as and, in some cases, may be more important than, the technical quality of the endodontic treatment in achieving and maintaining apical periodontal health.26 This finding emphasizes that leakage is an ongoing process pertinent to all aspects of treatment. The materials available today, however, are unable to totally prevent this process of leakage, either singularly or in combination.

Surveys have been described as important information tools that can identify present conditions and detail current philosophies, techniques, and needs.²⁷²⁸ Once the information is gathered, it can provide an overview of treatment rationales, which, when combined with scientific data and empirical, clinically reliable techniques, may lead to higher rates of successful outcomes in practice. Furthermore, key information may be gathered and tabulated in a timely fashion, assuring evidence-based guidelines for a scientific study.²⁹

The purpose of this study was to identify the pulpal findings encountered by practitioners when they access complete-coverage crowns that require NSRCT and the relevance of restoring this access permanently, in terms of coronal leakage. This information will help to establish guidelines for an evidence-based study to identify which materials minimize leakage in the restoration of crowned teeth that require NSRCT.

METHOD AND MATERIALS

The design of the questionnaire for this study was developed by a focus group of faculty from the disciplines of biostatistics and endodontics. The survey items were created to address a number of unresolved clinical issues. These issues included the practitioner's understanding of coronal leakage and the practitioner's preference of contemporary restorative materials to be used with various types of complete-coverage crowns. The questions focused on the clinical scenario of endodontically accessed teeth with preexisting complete-coverage crowns.

The survey package consisted of a cover letter stating instructions, rationale, and purpose for the questionnaire, the questionnaire itself, and a stamped, selfaddressed envelope. The survey had 8 short-answer questions. The questions applicable to this portion of the study are shown in Fig 1. The faculty focus group, as well as a group of endodontic graduate students, pretested the survey to ensure that the questions were clear, succinct, and accurately addressed the issues of interest.

A power analysis was used to identify the number of surveys required for a valid statistical analysis with a minimum of bias, assuming an anticipated response rate of 50%. The random sample consisted of 900 dental professionals, including active general practitioners (300), active prosthodontists (300), and active endodontists (300) throughout the United States. Mailing labels for these randomized groups were obtained from the following 3 associations, respectively: the American Dental Association, the American Association of Prosthodontists, and the American Association of Endodontists.

The survey covered different aspects of clinical scenarios and the dentists' choice of restorative material for scaling access openings following nonsurgical endodontic treatment through the various types of complete-coverage crowns. In part 1 of this survey, different case situations encountered in practice were addressed, including the longevity and failure of crowns, and pulpal condition, and the practitioners' views on the relevance of leakage to the ultimate success of the crown. Part 2 of this survey addressed the respondents' attitudes toward permanent restoration of teeth recently subjected to NSRCT and specific restorative techniques for sealing the access cavity of teeth treated through complete-coverage crowns.³⁰

After an interval of 60 days, a low response rate (16%) from general practitioners triggered a second mailing of the same questionnaire. After 90 days, all data were collected and analyzed statistically. Frequency tables and descriptive statistics were compiled for the various survey items. The attitudes and practices of general practitioners, prosthodontists, and endodontists, as ascertained from this survey, were compared using chi-squared tests of independence. All statistical analyses were performed with SPSS statistical software (version 9.0, SPSS).

RESULTS

Nine hundred surveys were mailed initially within a time span of 90 days. Of the 900 surveys sent out, 543 were completed and returned, representing a 60% response. This section of the survey targeted the issue of the longevity and failure of crowns, the pulpal condition on entry through a complete-coverage crown, the respondents' attitudes toward restoration of teeth recently subjected to NSCRT, and their views on the relevance of leakage to the success or failure of NSRCT.

Fig 1 Questionnaire items. (RCT) Root canal treatment.

I practice as a (an):	
Endodontist.	
Prosthodontist.	
General practitioner.	
When doing root canal treat	atment (RCT) through a crowned
Count are most nequent pu	np status i encounter is.
D Interrosis%	
D Les pet de DCT	%e,
D Other	70.
When performing RCT on a	a tooth with an artificial crown, I:
Go through the crow after RCT %	n and restore access opening
Remove the crown, it then recement the or	use as a temporary crown, and
Remove the crown, i a new crown after Bi	use as a temporary, and make
Bemove the crown, i	make a temporary crown, and the
create a new crown	after completion of the root canal
Cibor 76.	
- Outer	0/2
	/0.
Loonsider coronal leakage	as an important factor when
restoring an access openin	ng through a crown:
D Frequently	
D Seldom	
D Never	
(ACCESSED)	
In your practice, when RCT	T is needed on a crowned tooth,
what is the approximate ag	je of the crown?
O to 1 year.	
1 to 5 years.	
5 to 10 years.	
The difference of the second	

□ 10 to 15 years.

15 years or more.

The overall response rate to the first question (practice type) was 60% (543/900). Table 1 details the number of responses from each practitioner group. All practitioner groups had similarly high response rates; at least 55% of each practitioner group responded to this question.

The overall response rate to the second question (pulpal status) was 71% (346/543) (Table 2). There was a statistically significant difference (P < 0.001) between the response rate of prosthodontists (14/72=41%) and those of the other 2 groups of practitioners (endodontists, 191/191=100%; general prac-

titioners, 86/120=72%) who access teeth and identify the pulpal status. Most prosthodontists (58/72 [81%]) indicated, in the response "other," that they do not perform root canal treatment and added that they refer patients to an endodontist. Only 28% (34/120) of general practitioners refer patients to endodontists.

Further data collected from the second question (pulpal statis) indicated that endodontists and prosthodontists indentified the findings of necrosis and irreversible pulpitis on an equivalent basis (50% necrosis & 50% irreversible pulpitis) in symptomatic teeth with complete-coverage crowns. General practitioners identified necrosis in 70% of the cases and irreversible pulpitis in 30% of cases. Because of the small number of responses from prosthodontists (47%), there was statistically more of a difference in the response between endodontists and prosthodontists than there was between endodontists and general pratitioners.

The overall response rate to the third question (access route) was 70% (382/543). The responses to the question were categorized into 3 groups: (1) those who go through the crown to access the pulp chamber; (2) those who obtain access for NSRCT by removing the crown and using this crown as permanent restoration; and (3) those who obtain access for NSRCT with the original crown remaining as temporary, or making a provisional crown and creating a new complete coverage crown (Table 3). A statistically significant difference in the number of responses was recorded (P < 0.001) between prosthodontists (37%) and the other 2 groups of practitioners (endodontists, 100%): general practitioners, 69%).

The following data was obtained by those practitioners who responded "other" in the third question, in which no access route was selected by the practitioners: Sixty-three percent (110/175) of the prosthodontists refer the patients to an endodontist for the total procedure while only 30% (51/166) of general practitioners refer patients to endodontists for the whole procedure.

Endodontists and general practitioners obtain access through the crown significantly more often than do prosthodontists (P < 0.001) and showed a trend toward maintaining the existing crown as the final restoration. Prosthodontists used the crown as a provisional restoration or constructed a provisional acrylic resin complete-coverage restoration. This entry was statistically significant with regard to the response by both endodontists and general practitioners (P < 0.001).

The overall response to the fourth question was 97% (528/543). Table 4 indicates the respondents' beliefs about the importance of coronal leakage when the endodontically treated, crowned tooth is restored. All practitioner groups had similarly high response rates;

TABLE 1 Total survey return					
Practitioners	Sent	Received	Response rate		
Endodontists	300	202	67%		
Prosthedontists	300	175	58%		
General dentists	300	166	55%		
Total	900	543	60%		

TABLE 2 Total response to survey's second question (pulpal status)

Practitioners	Response	Rate
Endodontists	191/202	95%
Prosthodontists	72/175	41%
General dentists	120/166	72%
Total	383/543	71%

TABLE 3 Method of obtaining access to pulp chamber

	Endodontists		Prosthodontists		General practitioners		All practitioners	
Method	No.	%	No.	%	No.	%	No.	%
Access through crown	177/202	88	20/65	31	79/115	69	276/382	72
Remove the crown	14/202	7	22/65	34	29/115	25	65/382	17
Use artificial provisional crown	11/202	5	23/65	35	7/115	6	41/382	11
Total*	202/202	100	65/175	37	115/166	69	382/543	70

*Total number and percentage of responses to the question in relation to the number of surveys returned.

TABLE 4 Importance of coronal leakage when an access opening is restored through a crown

Response	Endodontists		Prosthodontists		General practitioners		All practitioners	
	No.	%	No.	%	No.	%	No.	%
Always	177/196	90	139/171	81	124/161	77	440/528	83
Frequently	12/196	6	14/171	8	23/161	14	49/528	9
Seldom	7/196	4	14/171	8	12/161	8	33/528	7
Never	0/196	0	4/171	3	2/161	1	6/528	1
Total*	196/202	97	171/175	98	161/166	97	528/543	97

*Total number and percentage of responses to the question in relation to the number of surveys returned.

TABLE 5 Age of the crown when a tooth requires nonsurgical root canal treatment

Age of crown	Endodontists		Prosthodontists		General practitioners		All practitioners	
	No.	%	No.	%	No.	%	No.	%
0–5 y	74/153	48	43/151	28	44/148	30	161/452	36
5-10 y	70/153	46	83/151	55	80/148	54	233/452	52
10 y or more	9/153	6	25/151	17	24/148	16	58/452	13
Total*	153/202	76	151/175	86	148/166	89	452/543	83

*Total number and percentage of responses to the question in relation to the number of surveys returned.

at least 97% of each practitioner group responded to the question. A chi-squared test of independence revealed no statistically significant differences among the 3 types of practitioners (endodontists, prosthodontists, and general practitioners) in the perceived importance of restoring access openings.

The overall response to the question regarding the age of the crown was 83% (452/543). While there was no statistically significant difference in response rates among the groups, endodontists had a lower response

rate (76%) than they had for the other questions. The data in Table 5 indicate that a significantly greater number of practitioners believe that crowned teeth will require NSRCT in 5 to 10 years (P < 0.001). When all responses were combined, 36% of practitioners (161/452) believed that teeth with complete-coverage crowns would require NSRCT in the first 5 years, 52% (233/452) expected it to be needed in the 5- to 10-year span, and 13% (58/452) predicted that it would be necessary after 10 years or more.

DISCUSSION

The total response to the survey (60%) compares with that attained by previous investigators who evaluated the response rates among dentists.²⁷³¹⁻³³ The low response rate of general practitioners (16%) necessitated the mailing of a second survey to obtain a sufficient representative sample from the general practitioner population (55%). The final response was equivalent to the level of response considered acceptable; a response rate of less than 50% in a dental population may be suspect.²⁸ Hovland et al²⁷ found no differences in attitudes, knowledge, or demographic data in the group that needed an additional request to return the questionnaire.

Endodontists (88%) and general practitioners (69%) indicated that they create endodontic access openings through complete-coverage crowns more often than do prosthodontists (31%). Notably, a significant number of prosthodontists (81%) indicated in the second question that they refer the endodontic treatment to their specialist of choice. Prosthodontists who initiate it as a provisional crown (34%), create an acrylic resin provisional restoration (35%), or create endodontic access openings through complete-coverage crowns.

The combination of extensive coronal restorations, such as crowns, and periodontal disease may have a greater impact on the viability of the dental pulp. Combined, all groups identified 5 to 10 years as the most common time period for pulpal demise in teeth with complete coverage restorations. Many endodontists (48%), however, identified pulpal degeneration at a much earlier stage, 1 to 5 years. This is attributable to the fact that endodontists treat pulpal inflammation and/or necrosis daily. Previous studies have identified the life span of crowns to be in a range similar to the 5- to 10-year range chosen in the survey.⁴³⁴⁻³⁶

The responses of the dental pulp to irritation, including caries, trauma, chemical insult, and thermal insult are multiple. Microscopic inflammatory changes in the pulp may be present in the complete absence of clinical symptoms and signs.37 Repeated episodes of caries, periodontal disease, and dental treatment are cumulative and ultimately approach a clinically significant threshold in which root canal treatment is essential, even when the tooth is asymptomatic. These teeth are not identified routinely and are said to exhibit a stressed pulp.38 The data collected in this survey suggest that the concept of a stressed pulp is valid and is therefore an issue to be considered during the treatment planning phase of the restorative treatment. These data also indicate that specialists do limit their practice to their chosen field.

Several investigators have identified coronal leakage as a major factor in bacterial contamination and the subsequent failure of nonsurgical root canal therapy^{6,30,21,25,24,39,40} Contamination of dentin by saliva and the penetration of the dentinal tubules by bacteria and their by-products through leakage have a detrimental effect on pulpal tissue.^{41,44} Leakage around the margin of a cast restoration frequently extends toward the pulp through the dentinal tubules. This is a problem that is extremely difficult to assess clinically and radiographically. The importance of the integrity of the restoration in the access opening and the crown therefore cannot be understated.⁶ The importance of leakage that can penetrate these coronal restorations is evidenced by the significant number of responses to this question (97%); most respondents (83%) identified leakage as always being significant.

CONCLUSION

The data presented constitutes the first part of a 4-part series. The first 2 parts discuss the findings of a survey sent to 900 active practitioners, resulting in the following conclusions:

- Respondents to the survey believe that leakage must be minimized when endodontic access openings are restored in artificial crowns on teeth that have undergone nonsurgical root canal treatment.
- Endodontists and general practitioners obtain access through complete-coverage crowns and maintain these crowns as final restorations more often than do prosthodontists. Prosthodontists obtain access through the crowns, but replace the artificial crowns once the treatment has been completed.
- The trend among practitioners is to limit practice to their specialty, however, general practitioners perform nonsurgical root canal treatment more frequently than do prosthodontists.
- A wide range of dental practitioners believe that the majority of teeth with complete-coverage fixed crowns will require NSRCT in 5 to 10 years.

ACKNOWLEDGMENTS

This research was supported in part by the Intramural Grant of the Baylor College of Dentistry, a member of the Texas A&M University System Health Science Center.

REFERENCES

 Cheung GSP. A preliminary investigation into the longevity and causes of failure of single unit extracoronal restorations. J Dent 1991;19:160–163.

- Bergenholtz G, Nyman S. Endodontic complications following periodontal and prosthetic treatment of patients with advanced periodontal disease. J Periodontol 1984;55:63–68.
- Jackson CR, Skidmore AE, Rice RT. Pulpal evaluation of teeth restored with fixed prostheses. J Prosthet Dent 1992; 67:323-325.
- Valderhaug J, Jokstad A, Ambjornsen E, Norheim PW, Assessment of the periapical and clinical status of crowned teeth over 25 years. J Dent 1997;25:97–105.
- Näpänkagas R, Salonen MA, Raustia AM. A 10-year followup study of fixed metal ceramic prosthodontics. J Oral Rehabil 1997;24:713–717.
- Goldman M, Laosonthorn P, White RR. Microleakage–Full crowns and dental pulp. J Endod 1992;18:473–475.
- Lowman JV, Burke RS, Pelleu GB. Patent accessory canals: Incidence in molar furcation region. Oral Surg Oral Med Oral Pathol 1973;36:580–584.
- Rubach WC, Mitchell DF. Periodontal disease, accessory canals and pulp pathosis. J Periodontol 1965;36:34-38.
- Langeland K, Rodriguez H, Dowden W. Periodontal discase, bacteria and pulpal histopathology. Oral Surg Oral Med Oral Pathol 1974;37:257–270.
- Belk CE, Gutmann JL. Perspectives, controversies and directives on pulpal-periodontal relationships. J Can Dent Assoc 1990;56:1013-1017.
- Massler M. Pulpal reaction to dental caries. Int Dent J 1967;17:441-460.
- Torneck CD. A report of studies into changes in the fine structure of the dental pulp human caries pulpitis. J Endod 1981;7:8–16.
- Langeland K. Tissue response to dental caries. Endod Dent Traumatol 1987;3:149–171.
- Bergenholtz GJ. Pathogenic mechanisms in pulpal disease. J Endod 1990;16:98–101.
- Langeland K, Histologic evaluation of pulp reactions to operative procedures. Oral Surg Oral Med Oral Pathol 1959;12:1235–1248.
- Langeland K. Histologic evaluation of pulp reactions to operative procedures. Oral Surg Oral Med Oral Pathol 1959;12:1357–1369.
- Langeland K. Effects of various procedures on the human dental pulp. Oral Surg Oral Med Oral Pathol 1961;14. 210-233.
- Langeland K, Langeland LK. Pulp reactions to crown preparations, impression, temporary crown fixation, and permanent cementation. J Prosthet Dent 1965;15:129-143.
- Bergenholtz GJ, Cox CG, Loesche WJ, Syed SA. Bacterial leakage around dental restorations: its effect in the dental pulp. J Oral Pathol 1982;II:439–450.
- Cox CF, Keall CL, Keall HJ, Ostro E, Bergenholtz, GJ. Biocompatibility of surface-sealed dental materials against exposed pulps. J Prosthet Dent 1987;57:1–8.
- Madison S, Wilcox LR. An evaluation of coronal microleakage in endodontically treated teeth. Part III. In vivo study. J Endod 1988;14:455–458.
- Seltzer S, Bender IB. The Dental Pulp: Biologic Considerations in Dental Procedures, ed 3. St Louis: Ishiyaku Euroamerica, 1990;349-373.
- Saunders WP, Saunders EM, Coronal leakage as a cause of failure in root canal therapy; A review. Endod Dent Traumatol 1994;10:105-108.

- Wu M-K, Wesselink PR. Endodontic leakage studies reconsidered. Part I. Methodology, application and relevance. Int Endod J 1993;26:37-43.
- Jeffrey IWM, Saunders WP. An investigation into the bond strength between a root canal sealer and root filling points. Int Endod J 1987;20:217–222.
- Ray H, Trope M. Periapical status of endodontically treated teeth in relation to the quality of the root filling and the coronal restoration. Int Endod J 1995;28:12–18.
- Hovland EJ, Romberg E, Moreland EF. Non response bias to mail survey questionnaires within a professional population. J Dent Educ 1980;44:270–274.
- Hovland EJ, Gutmann JL. How is mail survey questionnaire used in research? Dent Hyg 1980;54:410.
- Stamos DE, Gutmann JL. Survey of endodontic retreatment methods used to remove intraradicular posts. J Endod 1993; 19:366–369.
- Trautmann G, Gutmann JL, Nunn ME, Witherspoon DE, Shulman JD. Restoring teeth that are endodontically treated through existing crowns. II. Survey of restorative materials commonly used. Quintessence Int 2000;31:719–728.
- Cafferta GL, Goldberg HJ, Roghmann K, Fox R. Continuing education: Attitudes, interests, and experiences of practicing dentists. J Dent Educ 1975;39:793–800.
- Hovland EJ, Gutmann JL. Current endodontic therapy provided by the Maryland general dentist. J Md State Dent Assoc 1978;21:14–20.
- Wasilkoff PC, Maurice CG. Role of endodontics in current dental practice. J Am Dent Assoc 1976;93:800–805.
- Schwartz NL, Whitsett LD, Berry TG, Stewart JL. Unserviceable crowns and fixed partial dentures: Lifespan and causes for loss of serviceability. J Am Dent Assoc 1970;81:1395–1401.
- Walton JN, Gardner FM, Agar JR. A survey of crown and fixed partial denture failures: Length of service and reasons for replacement J Prosthet Dent 1986;56:416–421.
- Glantz PO, Rygc G, Jendresen MD, Nilner K, Quality of extensive fixed prosthodontics after five years. J Prosthet Dent 1984;52:475-479.
- Reeves R, Stanley HR. The relationship of bacterial penetration and pulpal pathosis in carious teeth. Oral Surg Oral Med Oral Pathol 1966;22:59–65.
- Abou-Rass M. The stressed pulp condition: An endodonticrestorative diagnostic concept. J Prosthet Dent 1982;48: 264–267.
- Saunders WP, Saunders EM. Assessment of leakage in the restored pulp chamber of endodontically treated multirooted teeth. Int Endod J 1990;23:28–33.
- Magura ME, Kafrawy AH, Brown CE Jr, Newton CW. Human saliva coronal microleakage in obturated root canals: An in vitro study. J Endod 1991;17:324-331.
- Kakehashi S, Stanley HR, Fitzgerald RJ. The effects of surgical exposures of dental pulps in germ-free and conventional laboratory rats. Oral Surg Oral Med Oral Pathol 1965; 20:340–349.
- Bergenholtz GJ, Lindhe J. Effect of soluble plaque factors on inflammatory reactions in the dental pulp. Scand J Dent Res 1975;83:153-158.
- Bergenholtz GJ. Effects of bacterial products on inflammatory reactions in the dental pulp bacteria. Scand J Dent Res 1977;85:122–129.
- Bergenholtz GJ. Inflammatory response of the dental pulp to bacterial irritation. J Endod 1981;7:100-104.

Copyright of Quintessence International is the property of Quintessence Publishing Company Inc. and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.