

## CLINICAL RESEARCH

# Treatment Outcome in Endodontics—The Toronto Study. Phase II: Initial Treatment

Mahsa Farzaneh, DDS, MSc, Sarah Abitbol, DDS, MSc, Herenia P. Lawrence, DDS, PhD, and Shimon Friedman, DMD

**The 4- to 6-yr outcome of initial (first-time) endodontic treatment was assessed for Phase II of the “Toronto Study.” In total, 442 teeth were treated by using flared preparation and vertical compaction of warm gutta-percha or step-back preparation and lateral compaction. With 126 teeth excluded (discontinuers: deceased and relocated patients), 163 dropouts, and 31 extracted, 122 (48% recall) were examined for outcome: “healed” (no apical periodontitis [AP], signs, symptoms) or “diseased” (AP, signs, or symptoms). Phase II was analyzed separately and combined with Phase I ( $n = 242$ ), using Chi-square and Fisher’s exact tests ( $p \leq 0.05$ ). The healed rate (combined sample, 85%) differed significantly for preoperative AP (absent, 93%; present, 79%), treatment technique (flared preparation and vertical compaction, 90%; step-back preparation and lateral compaction, 80%), gender (females, 90%; males, 79%), number of roots (1–92%;  $\geq 2$ –81%), and root-filling length (adequate, 87%; inadequate, 77%). Logistic regression revealed increased risk of disease for preoperative AP (odds ratio = 3.3) and technique (odds ratio = 2.3). This study confirmed AP and highlighted treatment technique as the main predictors of outcome in initial treatment.**

Systematic research on the outcome of initial (first-time) endodontic treatment is important to clinicians, who are expected to estimate prognosis and base treatment decisions on sound evidence, and also to patients undergoing treatment. In recent years, emphasis has been placed on evidence-based health care, and thus, also on the levels of evidence in published studies (1). Accordingly, only studies that rate high on the hierarchy of evidence (2–4) are considered as a basis for projecting prognosis, whereas others are considered to generate hypotheses. High ranking on the hierarchy

of evidence is determined by the design of the study, but also by adherence to parameters of sound methodology (2, 3). Observational cohort studies, such as those published on the outcome of endodontic treatment, can qualify if complying with sound methodology.

A recent review (5) of more than 60 observational cohort studies on the outcome and prognostic factors for initial treatment of apical periodontitis (AP) selected or excluded studies based on compliance with four methodology parameters: cohort, intervention, outcome assessment, and analysis. Only 12 observational cohort studies conformed to at least three of the four parameters (6–17). These selected studies form the current evidence base for the outcome and prognosis of initial endodontic treatment. Clearly, additional studies, consistent with adequate level of evidence, are needed to broaden that evidence base.

The most recent of the selected studies (17) reports on Phase I (September 1993 to December 1995) of the “Toronto Study” project. This project, established in 1993, is a continuous investigation of the 4- to 6-yr outcome of endodontic treatment performed by graduate endodontics students. Patient recall has been divided into 2-yr “phases.” The results regarding initial treatment for Phase I (17) revealed that the outcome (81% overall healed rate) was significantly better in teeth treated without the presence of AP. With AP present, the outcome was significantly better for single-rooted than for multirouted teeth. Several factors were associated with a large ( $\geq 10\%$ ), albeit statistically nonsignificant healing rate differential. Two factors were of particular interest: (a) number of treatment sessions in teeth with AP; and (b) treatment technique: flared canal preparation and vertical compaction of warm gutta-percha (FPVC) as described by Schilder (18, 19), or modified step-back preparation and lateral compaction of gutta-percha (SBLC) (20–22). The lack of significance for some of those factors is reflective of insufficient power because of the limited sample size of the Phase I study (17).

The objective of this study was to assess the outcome of initial endodontic treatment in Phase II of the Toronto Study project, alone and combined with Phase I. More specifically, the goal was to elucidate with greater power the effect on the outcome of specific preoperative, intraoperative, and postoperative factors, indicated by Phase I as potential determinants of the outcome of treatment and prevention of AP.

TABLE 1. Univariate distribution of the investigated factors in the treated population

Prognostic Factor	Phase II		Phase I & II	
	Inception Cohort % (n = 442)	Study Sample % (n = 122)	Inception Cohort % (n = 847)	Study Sample % (n = 242)
Preoperative				
Age				
≤45 yr	51	22	52	27
>45 yr	49	78	48	73
Gender				
Female	55	53	53	52
Male	45	47	47	48
Tooth type				
Anterior	21	19	20	19
Posterior	79	81	80	81
Tooth location				
Maxilla	50	52	52	53
Mandible	50	48	48	47
No. of roots				
1	29	30	30	31
≥2	72	70	70	69
Signs and symptoms				
Absent	33	39	35	35
Present	67	62	65	65
Radiolucency				
Absent	38	43	41	40
Present	62	57	59	60
Pulp status				
Responsive	33	35	35	33
Nonresponsive	67	65	65	67
Intraoperative				
Treatment sessions				
1	16	18	19	19
≥2	84	82	81	81
Technique				
SBLC	46	46	50	49
FPVC	51	50	47	46
Other*	3	4	3	5
Root-filling length				
Adequate	81	78	79	75
Short	7	6	8	8
Long	12	16	13	17
Root-filling voids				
Absent	85	85	82	83
Present	15	15	18	17
Sealer extrusion				
Absent	51	51	49	50
Present	49	49	51	50
Complications				
Absent	84	85	84	85
Present	16	15	16	15
Temporary seal material				
Temporary†	6	9	16	18
Definitive‡	94	91	84	82
Postoperative				
Restoration at follow-up				
Temporary		7		7
Definitive filling		30		30
Crown		63		63
Post				
Absent		59		52
Present		41		48

SBLC = modified step-back preparation, lateral compaction of gutta-percha; FPVC = flared preparation, vertical compaction of warm gutta-percha.

\* Modified step-back preparation, single gutta-percha cone and Ketac-Endo sealer.

† Cavit, ZOE, IRM.

‡ Amalgam, composite resin, glass ionomer, crown.

**TABLE 2. Bivariate analysis of associations between selected factors§ and the “healed” rate, 4 to 6 years after treatment for Phase II (n = 122) and Phases I and II combined (n = 242)**

Prognostic Factor	Phase II			Phase I & II		
	n	Healed (% n)	p Value	n	Healed (% n)	p Value
Preoperative						
<b>Gender</b>						
Female	65	92	0.058*	<b>126</b>	<b>90</b>	<b>0.025*</b>
Male	57	81		<b>116</b>	<b>79</b>	
Tooth type						
Anterior				47	92	0.15*
Posterior				195	83	
<b>No. of roots</b>						
1	36	94	0.146†	<b>76</b>	<b>92</b>	<b>0.036*</b>
≥2	86	84		<b>166</b>	<b>81</b>	
<b>Radiolucency</b>						
Absent	<b>52</b>	<b>94</b>	<b>0.038*</b>	<b>98</b>	<b>93</b>	<b>0.004*</b>
Present	<b>70</b>	<b>81</b>		<b>144</b>	<b>79</b>	
Intraoperative						
Treatment sessions						
1	22	96	0.3†			
≥2	100	85				
<b>Technique</b>						
SBLC	<b>56</b>	<b>80</b>	<b>0.031*</b>	<b>120</b>	<b>80</b>	<b>0.042*</b>
FPVC	<b>61</b>	<b>93</b>		<b>110</b>	<b>90</b>	
Other‡	5	100		12	83	
<b>Root-filling length</b>						
Adequate				<b>181</b>	<b>87</b>	<b>0.05*</b>
Inadequate				<b>61</b>	<b>77</b>	
Complications						
Absent	104	89	1†	206	86	0.079*
Present	18	78		36	75	
Postoperative						
Restoration at follow-up						
Definitive	113	89	1†			
Temporary	8	63				

SBLC = modified step-back preparation, lateral compaction of gutta-percha; FPVC = flared preparation, vertical compaction of warm gutta-percha.

\* Chi-squared test.

† Fisher's exact test.

‡ Modified step-back preparation, single gutta-percha cone and Ketac-Endo sealer.

§ Only factors associated with a healed rate differential of ≥10% presented.

Bold type face highlights statistical significance.

Based on the Phase I study results (17), it was hypothesized that the healed rate would be significantly higher for: (a) single-rooted than multirouted teeth; (b) treatment using FPVC than SBLC technique; and (c) treatment of teeth presenting with preoperative AP in two or more sessions than in one session.

## MATERIALS AND METHODS

The protocol for the Toronto Study project was established before treatment of patients was initiated. The methodology was described in detail in the previous report (17) and followed precisely in this study. The following is a brief summary.

1. The inception cohort of 442 teeth in 371 patients comprised all initial endodontic treatments performed from January 1996 to December 1997. Appropriate informed consent was obtained from all patients. Teeth requiring apexification were excluded. Supervised graduate students provided treatment in accordance with a structured protocol. Two treatment techniques were used: SBLC and FPVC. In addition, a small proportion of teeth were treated using modified step-back preparation and single gutta-

percha cone with a glass-ionomer cement sealer (Ketac-Endo, ESPE, Seefeld, Germany). Each technique was performed only on specific days of the week. Treatment technique was quasirandomized by allocating patients to clinical sessions according to availability and convenience.

2. All preoperative and intraoperative data were uniformly recorded at the time of treatment by the providers of treatment and entered into a database.
3. All patients were recalled and offered compensation for attending. Efforts were made to find relocated patients and to encourage nonresponders to attend. When treated teeth were noted to be lost, patients were questioned and the records of those who received regular care at the Faculty of Dentistry examined to establish the reasons for extraction.
4. All follow-up examinations were performed by the Phase II-designated examiner (M.F.), who was calibrated for use of the Periapical Index (PAI) (23), similarly for the Phase I examiner (S.A.) and co-investigator (S.F.) for the project. Interexaminer and intraexaminer reliability scores were calculated. PAI scores were dichotomized to reflect absence (PAI ≤ 2) or presence

**TABLE 3. Stratified bivariate analysis of associations between selected factors\* and the "healed" rate in teeth treated without preoperative apical periodontitis, 4 to 6 years after treatment in Phase II (n = 52) and Phases I and II combined (n = 98)**

Prognostic Factor	Phase II			Phase I & II		
	n	Healed (% n)	p Value	n	Healed (% n)	p Value
Preoperative						
Gender						
Female	30	100	0.07†	58	97	0.118†
Male	22	86		40	87	
Intraoperative						
Complications						
Absent				81	95	0.098†
Present				17	82	
Postoperative						
Restoration at follow-up						
Definitive	47	96	1†			
Temporary	5	80				

\* Only factors associated with a healed rate differential of  $\geq 10\%$  presented.

† Fisher's exact test.

- (PAI  $\geq 3$ ) of AP. The tooth was the unit of evaluation, with multirrooted teeth assigned the highest score of all roots.
- Outcome assessment was based on clinical and radiographic measures, and the periapical tissues classified as "healed" (absence of AP, signs, and symptoms other than tenderness to percussion), or as having "disease" (presence of AP, signs, or symptoms). Teeth presenting without clinical signs or symptoms were considered "functional" regardless of the PAI score.
  - Power analyses were performed (not shown) based on the Phase I study results (17) to estimate the required sample size for investigating specific factors with 80% power and 5% significance. For example, 100 recalled teeth per group were required to substantiate a 17% difference in the outcome related to treatment technique (SBLC versus FPVC) in teeth with AP.

### Analysis

Statistical analysis was performed on both the data of this study (Phase II) and the combined data from Phases I and II. It included univariate description using percent frequencies and bivariate associations between the treatment outcome and preoperative, intraoperative, and postoperative factors, using Chi-square test of proportions and Fisher's exact test. Multivariate analysis to evaluate joint associations among various factors was performed on the combined data only, using logistic regression models. The dependent variable in all analyses was the dichotomous outcome, healed versus disease. All tests were performed as two-tailed and interpreted at the 5% significance level. Analysis of the complete sample was followed by stratified analyses of teeth treated without or with preoperative AP, both for the Phase II study data and the combined data. All investigated factors are listed in Table 1.

### RESULTS

Cohen's kappa score for interexaminer agreement between the Phase II examiner (M.F.) and the Phase I examiner (S.A.) as well as the co-investigator (S.F.) were both  $\kappa = 0.8$ . The intraexaminer agreement was  $\kappa = 0.8$ . These scores indicated "good agreement" (24).

### Phase II Sample

The inception cohort of 371 patients and 442 teeth was distributed into the following categories: (a) discontinuers (excluded), 126 teeth from 4 deceased and 105 relocated patients who could not be contacted; (b) dropouts, 163 teeth from 11 patients who declined recall and 121 patients who did not respond; and (c) attending, 153 teeth (48% recall rate) from 130 patients, including 122 teeth examined for outcome (study sample) and 31 extracted teeth (3 for advanced periodontal disease, 12 for restorative considerations, 16 for unknown reasons). The examined study sample is compared to the inception cohort in Table 1. Response bias analysis with respect to preoperative radiolucency (Chi-square = 0.97;  $df = 1$ ;  $p = 0.32$ ), as well as other factors (results not shown), revealed that the two populations did not differ significantly.

At the end point of the Phase II study, 106 teeth (87%) were classified as healed and 16 as having disease. The bivariate analysis (Table 2) identified only two statistically significant associations with a higher healed rate for treatment without preoperative AP than with AP, and treatment using FPVC than SBLC. Five additional factors were associated with "large" ( $\geq 10\%$ ) healed rate differentials that were not statistically significant.

Of the 106 teeth classified as healed, 3 presented with slight tenderness to percussion. Of the 16 teeth classified as having disease, 4 (25%) presented signs and symptoms of which 1 demonstrated a sinus tract and a PAI score of 1. Thus in total, 115 teeth (103 healed and 12 having disease) of 122 examined (94%) were free of any signs or symptoms, or fully functional. Of 15 teeth with PAI  $\geq 3$ , the lesion was smaller compared with the preoperative size (5 teeth, 33%), unchanged (4 teeth, 27%), or increased/new (6 teeth, 40%).

Of 52 teeth treated without preoperative AP, 49 (94%) remained healed. Stratified analysis (Table 3) identified only two factors associated with large healed rate differentials but no statistical significance. Of 70 teeth treated with preoperative AP, 57 (81%) had healed. Stratified analysis (Table 4) identified only one statistically significant association with a higher healed rate for treatment using FPVC than SBLC. Eight additional factors were associated with large healed rate differentials that were not statistically significant.

**TABLE 4. Stratified bivariate analysis of associations between selected factors\* and the “healed” rate, in teeth treated with preoperative apical periodontitis, 4 to 6 years after treatment in Phase II (n = 70) and Phases I and II (n = 144) combined**

Prognostic Factor	Phase II			Phase I & II		
	n	Healed (% n)	p Value	n	Healed (% n)	p Value
<b>Preoperative</b>						
<b>Age</b>						
≤45 yr	15	92	0.436‡			
>45 yr	55	78				
<b>Tooth type</b>						
Anterior				33	88	0.16†
Posterior				111	77	
<b>Tooth location</b>						
Maxilla	33	88	0.19†			
Mandible	37	76				
<b>No. of roots</b>						
1	22	91	0.204‡	<b>49</b>	<b>90</b>	<b>0.021†</b>
≥2	48	77		<b>95</b>	<b>74</b>	
<b>Pulp status</b>						
Responsive	64	83	1‡			
Nonresponsive	6	67				
<b>Intraoperative</b>						
<b>Treatment sessions</b>						
1				17	70	0.351†
≥2				127	80	
<b>Technique</b>						
SBLC	<b>34</b>	<b>73</b>	<b>0.049†</b>	<b>69</b>	<b>72</b>	<b>0.018†</b>
FPVC	<b>34</b>	<b>91</b>		<b>68</b>	<b>88</b>	
Other§	2			7	71	
<b>Root-filling length</b>						
Adequate				106	83	0.057†
Inadequate				38	68	
<b>Sealer extrusion</b>						
Absent	34	77	0.185†			
Present	36	89				
<b>Complications</b>						
Absent	60	83	1‡	125	81	0.231‡
Present	10	70		19	68	
<b>Postoperative</b>						
<b>Restoration at follow-up</b>						
Definitive	67	84	0.086‡			
Temporary	3	33				
<b>Post</b>						
Absent	44	86	0.209‡	84	83	0.145†
Present	26	73		60	73	

SBLC = modified step-back preparation, lateral compaction of gutta-percha; FPVC = flared preparation, vertical compaction of warm gutta-percha.

\* Only factors associated with a healed rate differential of ≥10% presented.

† Chi-squared test.

‡ Fisher's exact test.

§ Modified step-back preparation, single gutta-percha cone and Ketac-Endo sealer.

Bold type face highlights statistical significance.

### Combined Phase I and II Sample

The combined examined sample included 242 teeth (50% recall rate) from 215 patients. Once again, response bias analysis with respect to preoperative radiolucency (Chi-square = 0.18;  $df = 1$ ;  $p = 0.67$ ), as well as other factors (results not shown), revealed that this combined sample and the total inception cohort (847 teeth in 715 patients) did not differ significantly (Table 1).

Of the combined sample, 205 teeth (85%) were classified as healed and 37 as having disease. A total of 231 teeth (202 healed and 29 having disease) of the 242 examined (95%) were free of any signs and symptoms, or fully functional. Of 36 teeth with PAI ≥ 3, the lesion was smaller compared with the preoperative size (16 teeth, 45%), unchanged (8 teeth, 22%), or increased/new (12 teeth, 33%).

The bivariate analysis (Table 2) identified only five statistically significant associations with a higher healed rate for females than males, treatment without preoperative AP than with AP, single-rooted than multirouted teeth, treatment using FPVC than SBLC, and adequate root-filling length (0–2 mm from the root end) than inadequate length (longer or shorter). Two additional factors were associated with large healed rate differentials without statistical significance.

Logistic regression analysis (Table 5) identified the presence of preoperative AP and the treatment technique as the only significant predictors of the outcome with odds ratios of 3.29 and 2.29, respectively. The potential confounding of the result pertaining to treatment technique by other factors shown to be associated with large differentials in outcome was examined and excluded (Table

**TABLE 5. Logistic regression model of the outcome of initial endodontic treatment, 4 to 6 years after treatment for Phases I & II (n = 242)**

Predictor	Adjusted Odds Ratio	95% Confidence Interval	p Value
<b>Preoperative radiolucency (0 = absent, 1 = present)</b>	<b>3.29</b>	<b>1.35–8.05</b>	<b>0.009</b>
No. of roots (0 = single, 1 = multiple)	2.35	0.91–6.09	0.078
<b>Root-filling technique (0 = FPVC, 1 = SBLC)</b>	<b>2.29</b>	<b>1.04–5.05</b>	<b>0.04</b>

SBLC = modified step-back preparation, lateral compaction of gutta-percha; FPVC = flared preparation, vertical compaction of warm gutta-percha.  
 Bold type face highlights statistical significance.

**TABLE 6. Bivariate analysis between selected factors and treatment technique**

Prognostic Factor	Treatment Technique		p Value*
	FPVC n (%)	SBLC n (%)	
Gender			
Female	58 (53)	61 (52)	0.929
Male	52 (47)	56 (48)	
No. of roots			
1	35 (32)	33 (28)	0.553
≥2	75 (68)	84 (72)	
Radiolucency			
Absent	42 (38)	49 (42)	0.57
Present	68 (62)	68 (58)	
Root-filling length			
Adequate	85 (77)	84 (72)	0.334
Inadequate	25 (23)	33 (28)	
<b>Sealer extrusion</b>			
<b>Absent</b>	<b>42 (38)</b>	<b>66 (57)</b>	<b>0.005</b>
<b>Present</b>	<b>68 (62)</b>	<b>50 (43)</b>	

FPVC = flared preparation, vertical compaction of warm gutta-percha; SBLC = modified step-back preparation, lateral compaction of gutta-percha.

Bold type face highlights statistical significance.

\* Chi-squared test.

6). As expected, sealer extrusion was significantly more frequent with treatment using FPVC than SBLC. To further clarify the clinical significance of treatment technique, calculation (not shown) of the “numbers needed to treat” (25) was performed. It revealed that for every 11 teeth treated using FPVC rather than SBLC, one undesirable outcome (disease) was prevented.

Of 98 teeth treated without preoperative AP, 92 (94%) remained healed. Stratified analysis (Table 3) identified only two factors associated with large healed rate differentials but no statistical significance. Of 144 teeth treated with AP present, 114 (79%) had healed. Stratified analysis (Table 4) identified only two statistically significant associations with a higher healed rate for single-rooted than multirouted teeth, and treatment using FPVC than SBLC. Five additional factors were associated with large healed rate differentials but no statistical significance.

## DISCUSSION

This prospective, observational cohort study assessed the 4- to 6-yr outcome of initial endodontic treatment for the second phase of the modular Toronto Study project. As suggested previously (17), the study design conformed to parameters of sound method-

ology (5). The cohort was enrolled at a uniform point—time of intervention—regardless of prognosis or complicating factors. The majority of the patients was referred from the undergraduate clinic because of expected technical difficulty or after complications had occurred mid-treatment. Few patients were referred from the emergency clinic, and even fewer from general dentists in the community. These specific patterns of patient referral suggested the results of this study might not be generalized beyond the selected study cohort.

The recall rate of 48% in the Phase II study was comparable to that in Phase I (51%) and below that required for high level of evidence (2). The high number of relocated (discontinuers) and nonresponding (dropout) subjects suggested the study cohort was heterogeneous and transient. Indeed, in a previous epidemiological study (26) conducted on first-time patients at the University of Toronto Faculty of Dentistry, the cohort was characterized by a large percentage of immigrants. However, because the examined study sample did not differ significantly from the inception cohort, the study apparently was not subject to response bias.

Close supervision of the treatment providers by qualified practicing endodontists (6:1 ratio) suggested that treatment decisions were consistent with those made by clinicians in specialty practices. Treatment procedures conformed to a predetermined protocol and accepted standard of care. Rotary instrumentation and microscopes, the most recent additions to the endodontic armamentarium, were not yet used at the time Phase II patients were treated. Such adjuncts may have affected the results, but to what extent is speculative.

The examiners in Phases I and II were calibrated and blinded to the preoperative status of the teeth to ascertain uniform assessment of outcome (17). The dichotomized outcome classification excluded an “incomplete healing” or “uncertain” category, such as was used in several of the selected studies (7, 8, 15, 16). This was in keeping with the observation period of more than 4 yr by which time healing is expected to be complete (6). Nevertheless, reduction in lesion size among teeth having disease also was reported, as a basis for further interpretation of the reported results. As previously suggested (27), tenderness to percussion, when presenting alone, was not interpreted as a sign of AP considering that it also can result from traumatic occlusion, food impaction, and periodontal disease.

This study benefited from the ability to combine the samples from Phases I and II of the Toronto Study project. The double sample size facilitated assessment of the effect of the investigated factors on the outcome of treatment, having better power than that of either phase alone. The comparable univariate distribution of the different factors in the two cohorts suggested that neither cohort had a specific effect on the results.

Based on clinical and radiographic outcome measures, the overall healed rate for the combined sample (Phases I and II) was 85%. If only the radiographic measure was used, the healed rate would have remained 85%, demonstrating the asymptomatic nature of posttreatment AP (5). Conversely, using only the clinical measure, 95% of the teeth would have been classified as having a favorable outcome. Thus, the absence of symptoms is insufficient as a measure of healing. Patients should be encouraged to attend follow-up examinations after endodontic treatment to assess the outcome, even if they are asymptomatic. Nevertheless, absence of symptoms does allow the tooth to remain “functional.” This dimension of outcome should not be overlooked when communicating to patients the benefits associated with endodontic treatment vis-à-vis tooth extraction and replacement.

In teeth treated without preoperative AP, the healed rate was 94% (combined sample)—in the middle of the range (88–97%) reported in previous studies (6–8, 11, 12). None of the analyzed factors significantly affected this outcome. Clearly, with the limited sample size of teeth treated without preoperative AP in the present study, the relatively small difference associated with these factors could not be substantiated statistically.

In teeth treated with preoperative AP present, the healing rate was 79%—also in the middle of the previously reported range (73–90%) (6–16). It is noteworthy that 45% (combined sample) of the teeth having disease at follow-up demonstrated reduced lesions relative to the preoperative size. Although size reduction does not suggest that the lesion has healed, it may be a sign of slow-progressing healing. In a recent study (28), as many as 6% of teeth that had persistent AP 10 yr after treatment have been observed to completely heal 10 to 17 yr later. This finding should be communicated to patients to emphasize the need for extended follow-up as long as complete healing has not been observed.

The effect of the treatment technique on outcome has been the subject of debate for many years (8, 29). Although numerous *in vitro* studies have compared different techniques (30–33), FPVC and SBLC have not been directly compared for treatment outcome in a prospective manner. Thus, the Toronto Study project seems to be the first such attempt. The treatment technique emerged as the only factor significantly affecting the outcome, other than preoperative presence or absence of AP, as confirmed both by the bivariate (10% higher healing rate for FPVC) and the multivariate analyses. The potential confounding effect of this result by other factors was excluded. The healing rate differential associated with the treatment technique was greater in teeth treated with preoperative AP than in those treated without AP, and significance was confirmed only for the former group. Clearly then, the significant effect of the treatment technique on outcome was specific to teeth with preoperative AP. The FPVC technique, as taught in the Graduate Endodontics Clinic at the University of Toronto, strictly adhered to the original description by Schilder of the cleaning and shaping protocol (19) and vertical compaction of warm gutta-percha (18) using Kerr Pulp Canal Sealer (Kerr, Romulus, MI). The main alternative technique taught (SBLC) comprised step-back cleaning and shaping (20), often modified to include extensive apical reaming (21), and lateral compaction of gutta-percha (22) with Roth's 801 sealer (Roth International Ltd., Chicago, IL). Because the database was designed for entries of the root-filling technique, but not the cleaning and shaping protocol, the effect of the cleaning and shaping component could not be differentiated from that of the root-filling component. Thus, the technique described by Schilder (18, 19), as a complete concept, yielded a better outcome than SBLC. However, because this study was not designed specifically to compare the two treatment techniques, e.g. it was not a randomized, controlled trial, the result can only be considered as suggestive. Clearly, this novel finding requires corroboration by further studies, including future phases of the Toronto Study. Ultimately, the effect of the treatment technique on the outcome will have to be confirmed by future randomized, controlled trials.

Three factors, two preoperative and one intraoperative, were shown by the bivariate analysis to significantly affect the outcome; however, their effect was not substantiated by the multivariate analysis. These three factors are discussed below; their prognostic importance requires further investigation.

The outcome differed for single-rooted and multirouted teeth, as previously observed in the Phase I study (17) only for teeth with preoperative AP. Whether reflecting the complexity of eliminating root canal infection in the multirouted teeth or just the use of the tooth as the unit of evaluation (5), this finding suggested a practical application: clinicians can better appraise patients of the prognosis by citing the expected healing rate for the specific tooth type, rather than an average healing rate for single-rooted and multirouted teeth. It should be noted, however, that this finding was contrary to that of Strindberg (6) and Engström et al. (7).

Gender has not been found to significantly affect the outcome in the selected studies (11, 17). The potential confounding effect of other factors on this finding was assessed and excluded (tests not shown), and no explanation could be offered for this observation.

The outcome also differed for the apical extent of the root filling. "Adequate" was defined as 0 to 2 mm short of the radiographic root end, whereas shorter or longer extents were grouped as "inadequate." Only 25% of the teeth had inadequate root-filling length, and among these, approximately two-thirds were long. Extrusion of the root filling beyond the apex has been shown previously to adversely affect the outcome in teeth with preoperative AP (6–8, 11). Indeed, the largest healing rate differential related to root-filling length (15%) was observed among teeth with AP. It has been suggested that this adverse effect could be a result of over-instrumentation and subsequent transportation of contaminated debris periapically (5, 11, 34), rather than the periapical extrusion of the root-filling material *per se*.

Large ( $\geq 10\%$ ) differences in outcome, although not statistically significant, were associated with eight additional factors. It is expected that with the completion of successive phases of the Toronto Study project, the increased sample size will eventually allow assessment of the true prognostic value, if any, of these factors. Most factors assessed, however, were associated with only small ( $< 10\%$ ) and nonsignificant differences in outcome. This observation was consistent with the majority of previous selected studies that have found the following factors did not affect outcome: age (8), tooth location (15), preoperative symptoms (9, 11, 15), periodontal condition (11), occurrence of intra-appointment flare-ups (8, 9, 11), and final restoration after endodontic therapy (13).

Supported in part by the Canadian Academy of Endodontics Endowment Fund.

The authors thank Ms. Tamara Arenovich, Ms. Jewel Randolph, and Ms. Annemarie Polis for their valuable assistance in the preparation of this manuscript.

Drs. Farzaneh, Abitbol, and Friedman are affiliated with the Discipline of Endodontics, and Dr. Lawrence with the Discipline of Community Dentistry, Faculty of Dentistry, University of Toronto, Toronto, Ontario, Canada.

Address requests for reprints to Dr. Shimon Friedman, Professor and Head, Endodontics, Faculty of Dentistry University of Toronto, 124 Edward Street, Toronto, Ontario M5G 1G6, Canada. E-mail: s.friedman@utoronto.ca.

## References

- Kim M, Lin J, White R, Niederman R. Benchmarking the endodontic literature on Medline. *J Endodon* 2001;27:470–3.
- Department of Clinical Epidemiology and Biostatistics, McMaster University. How to read clinical journals: III. To learn the clinical course and prognosis of disease. *Can Med Assoc J* 1981;124:869–72.
- Sackett D, Richardson W, Rosenberg W, Haynes R. Evidence-based

medicine: how to practice and teach EBM. London: Churchill Livingstone, 1997.

4. Fletcher R, Fletcher S, Wagner E. *Clinical epidemiology: the essentials*. 2nd ed. Baltimore: Williams & Wilkins, 1988.

5. Friedman S. Prognosis of initial endodontic treatment. *Endod Topics* 2002;2:59–88.

6. Strindberg LZ. The dependence of the results of pulp therapy on certain factors. An analytic study based on radiographic and clinical follow-up examination. *Acta Odontol Scand* 1956;14(Suppl 21).

7. Engström B, Hard AF, Segerstad L, Ramström G, Frostell G. Correlation of positive cultures with the prognosis for root canal treatment. *Odontol Revy* 1964;15:257–70.

8. Kerekes K, Tronstad L. Long-term results of endodontic treatment performed with a standardized technique. *J Endodon* 1979;5:83–90.

9. Byström A, Happonen RP, Sjögren U, Sundqvist G. Healing of periapical lesions of pulpless teeth after endodontic treatment with controlled asepsis. *Endod Dent Traumatol* 1987;3:58–63.

10. Ørstavik D, Kerekes K, Eriksen HM. Clinical performance of three endodontic sealers. *Endod Dent Traumatol* 1987;3:178–86.

11. Sjögren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. *J Endodon* 1990;16:498–504.

12. Ørstavik D. Time-course and risk analyses of the development and healing of chronic apical periodontitis in man. *Int Endod J* 1996;29:150–5.

13. Sjögren U, Figdor D, Persson S, Sundqvist G. Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. *Int Endod J* 1997;30:297–306.

14. Trope M, Delano EO, Ørstavik D. Endodontic treatment of teeth with apical periodontitis: single vs. multivisit treatment. *J Endodon* 1999;25:345–50.

15. Weiger R, Rosendahl R, Löst C. Influence of calcium hydroxide intracanal dressings on the prognosis of teeth with endodontically induced periapical lesions. *Int Endod J* 2000;33:219–26.

16. Peters LB, Wesselink PR. Periapical healing of endodontically treated teeth in one and two visits obturated in the presence or absence of detectable microorganisms. *Int Endod J* 2002;35:660–7.

17. Friedman S, Abitbol S, Lawrence HP. Treatment outcome in endodontics: the Toronto Study. Phase 1: initial treatment. *J Endodon* 2003;29:787–93.

18. Schilder H. Filling root canals in three dimensions. *Dent Clin North Am* 1967;723–44.

19. Schilder H. Cleaning and shaping the root canal. *Dent Clin North Am* 1974;269–96.

20. Clem WH. Endodontics in the adolescent patient. *Dent Clin North Am* 1969;13:483.

21. Tronstad L. *Clinical endodontics*. New York: Thieme Medical Publishers, 1991.

22. Walton RE, Johnson WT. Obturation. In: Walton RE, Torabinejad M, eds. *Principles and practice of endodontics*. 2nd ed. Philadelphia: WB Saunders, 1996.

23. Ørstavik D, Kerekes K, Eriksen HM. The periapical index: a scoring system for radiographic assessment of apical periodontitis. *Endod Dent Traumatol* 1986;2:20–34.

24. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159–74.

25. Guyatt G, Jaeschke R, Heddle N, Cook D, Shannon H, Walter S. Basic statistics for clinicians 1. Hypothesis testing. *Can Med Assoc J* 1995;152:27–32.

26. Dugas NN, Lawrence HP, Teplitsky PE, Pharoah MJ, Friedman S. Periapical health and treatment quality assessment of root-filled teeth in two Canadian populations. *Int Endod J* 2003;36:181–92.

27. Friedman S, Löst C, Zarrabian M, Trope M. Evaluation of success and failure after endodontic therapy using a glass ionomer cement sealer. *J Endodon* 1995;21:384–90.

28. Molven O, Halse A, Fristad I, MacDonald-Jankowski D. Periapical changes following root-canal treatment observed 20–27 years postoperatively. *Int Endod J* 2002;35:784–90.

29. Pettiette MT, Delano EO, Trope M. Evaluation of success rate of endodontic treatment performed by students with stainless-steel K-files and nickel-titanium hand files. *J Endodon* 2001;27:124–7.

30. Siqueira JF Jr, Rocas IN, Santos SR, Lima KC, Magalhaes FA, de Uzeda M. Efficacy of instrumentation techniques and irrigation regimens in reducing the bacterial population within root canals. *J Endodon* 2002;28:181–4.

31. Weiger R, ElAyouti A, Löst C. Efficiency of hand and rotary instruments in shaping oval root canals. *J Endodon* 2002;28:580–3.

32. Gencoglu N, Garip Y, Bas M, Samani S. Comparison of different gutta-percha root filling techniques: Thermafil, Quick-Fill, System B, and lateral condensation. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2002;93:333–6.

33. Wu M, Kast'akova A, Wesselink PR. Quality of cold and warm gutta-percha fillings in oval canals in mandibular premolars. *Int Endod J* 2001;34:485–91.

34. Yusuf H. The significance of the presence of foreign material periapically as a cause of failure of root treatment. *Oral Surg Oral Med Oral Pathol* 1982;54:566–74.