CLINICAL ARTICLE

A clinical radiographic retrospective assessment of the success rate of single-visit root canal treatment

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Abstract

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Aim To determine retrospectively the clinical and radiographic success rate of single-visit root canal treatment performed in a busy endodontic practice using contemporary techniques of canal cleaning, shaping and obturation.

Summary Seven hundred and sixty-eight single-visit cases, of which 223 presented for a re-examination appointment ranging from 6 months to 4 years from the day of treatment, were considered. Four endodontists provided examinations for both root canal treatment and re-examinations. Clinical and radiographic data were used to form an overall impression of the outcomes for each case at the time of re-examination. Available demographics and treatment information of these 223 cases were compiled for comparison. The number of treatment visits was not determined by a pretreatment diagnosis or a re-assessment of the pulp status upon entry into the tooth; therefore both vital and necrotic cases, as well as those with and without periradicular pathosis, were included. Statistical analysis was carried out using Chi-square tests and considered variations in failure rates based on gender, provider, tooth type, position and arch. A *t*-test was used to evaluate data on age. The overall success rate was 89.2%. No statistically significant differences were seen based on gender, age, arch or provider. Statistically, anterior teeth were more successful than posterior teeth.

Key learning points

- The success rate of single-visit root canal treatment in this study is comparable to previous studies of teeth treated in a single visit, as well as those treated in multiple visits, with the placement of interappointment calcium hydroxide.
- The provision of single-visit root canal treatment using modern techniques of root canal cleaning, shaping and obturation can be considered as a viable method for the retention of natural teeth within contemporary treatment planning concepts.

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- Future studies on the outcomes of contemporary endodontic treatment should be designed and implemented to use prospective, randomized clinical trials in which the re-examination rate is high.

Keywords: clinical, non-surgical root canal treatment, radiographic, single-visit, success.

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Introduction

Historically, root canal treatment was performed in multiple visits primarily to ensure 'sterility' of the root canal system prior to obturation. Culturing techniques were used to determine the nature of the root canal flora immediately upon entry to the canal, during therapy and prior to obturation. Culture techniques used, however, were fraught with shortcomings, and in due course, the findings were found to be unreliable (Bender & Seltzer 1964) and this methodology was virtually abandoned.

Along with the determination of bacterial species during root canal treatment was the advocated use of a wide variety of antimicrobial agents to eliminate microbes. In addition to killing bacteria, these agents, primarily phenolic compounds, were also highly irritating to the periradicular tissues (Messer & Feigal 1985, Koontongkaew *et al*. 1988). Overzealous use of these medicaments led to a multitude of postoperative problems that were erroneously identified as a persistent periradicular infection. Hence, this led to the inappropriate and excessive use of antibiotics to control the so-called 'infection'. Ultimately, the deleterious effects of these medicaments were identified (Messer & Feigal 1985) and their routine clinical use was discontinued. This led to one of the two courses of treatment – either treat the root canal in one visit or seek an intracanal medicament that does not injure the periradicular tissues.

Those who believe that successful root canal treatment can be accomplished in one visit have rationale in the literature. Studies concerning postoperative pain (Fox *et al*. 1970, Pekruhn 1981, Mulhern *et al*. 1982, Oliet 1983, Alaçam 1985, Fava 1994, Eleazer & Eleazer 1998), as well as healing rates (Soltanoff 1978, Pekruhn 1986, Weiger *et al*. 2000), show the treatment outcomes to be similar, whether completed in one visit or in multiple visits. Along with these advantages are the benefits of increased patient acceptance and limiting duplicate procedures (Weiselberg & Vogelson 1983). Single-visit treatment means at least one fewer appointment. This decreases the number of operative procedures, including additional anaesthesia, gingival trauma from rubber dam placement, re-learning canal irregularities, angulations and curvatures using potentially irritating irrigants, as well as eliminating the risk of interappointment leakage through temporary restorations. These benefits, along with logistical patient management issues, such as loss of time from work and family, increase patient acceptance.

Considering the disparate views on the potential advantages and disadvantages of single-visit root canal treatment, a study drawing from the practices of experienced clinicians who treat root canals in a single visit would establish a foundation on which to base our treatment decisions. Weiger *et al*. (2000) published a study comparing cases treated in one visit to those in which there was an interappointment placement of calcium hydroxide for at least 7 days followed by obturation at the second appointment. Sixty-seven of the 73 patients were re-examined. The two groups included 36 teeth that were treated in one visit and 31 teeth that were completed in two visits. Healing was evaluated at re-examination, which was from 1 to 5 years after treatment. The healing rate increased over time, which

exceeded 90% after 5 years. Fifty-two teeth showed complete healing, 11 had incomplete healing and 4 teeth failed, which separated into complete healing in 30 of the 36 cases in the one-visit group and 22 of the 31 teeth in the multiple-visit category (83.3% vs. 70.9%, respectively).

Contemporary studies comparing single-visit to multiple-visit treatment differ in several areas. The amount and concentration of sodium hypochlorite and EDTA used for root canal irrigation and disinfection, as well as interappointment medicaments and cleaning and shaping techniques, vary. These factors may explain the wide range of success rates in the endodontic literature. Table 1 summarizes some of the studies that have evaluated single-visit and multiple-visit treatment modalities, including methods of cleaning and shaping, nature of irrigants and intracanal medicaments. Because of these variabilities, clear conclusions regarding causes of treatment failure are difficult to establish amongst the studies.

Proponents of multiple-visit procedures contend that the antimicrobial property of interappointment calcium hydroxide placement is required to ensure successful periradicular healing (Byström & Sundqvist 1985, Sjögren *et al*. 1997, Trope *et al*. 1999), although predictable levels of bacterial reduction via refined cleaning and shaping techniques in one appointment may negate this need (Card *et al*. 2002). Furthermore, when flare-ups occur during multiple-visit procedures, they can be addressed prior to obturation (Soltanoff 1978). This is not an option in a single-visit treatment regimen. When flare-ups occur, non-surgical re-treatment or surgical intervention is usually necessary.

Well-controlled clinical research is still needed to establish the factors associated with successful implementation of single-visit treatment. As a result, two divided schools of thought continue to exist concerning the number of visits necessary to achieve predictable success with root canal treatment. The purpose of this study was to determine retrospectively the clinical success rate of single-visit root canal treatment in a busy, contemporary, private practice setting, and to identify demographic and clinical similarities between those cases that succeed and those that fail.

Materials and methods

Records of all patients seen in a private practice limited to endodontics in Dallas, TX, USA from 1996 to 1997 were screened retrospectively for initiation and completion of non-surgical root canal treatment in one visit. This resulted in 768 single-visit cases, of which 223 (29% recall rate) presented for a re-examination appointment ranging from 6 months to 4 years from the day of treatment. Clinical and radiographic data gathered by the practitioners were combined to form an overall decision of success or failure for each case at the time of re-examination. Demographics and treatment information were compiled for comparison using the FOXPRO (Realtime Systems, Walnut Creek, CA, USA) computer system. This computer program was discontinued in June 2000. The earliest charts available for evaluation were of January 1996; therefore, the period from January 1996 to December 1997 was chosen for retrospective evaluation resulting in a minimum period of 2 years and 6 months from treatment.

Four clinicians completed evaluations for both treatment and re-examination. The number of treatment visits was not determined by any preoperative diagnosis; therefore, both vital and necrotic cases, as well as those with and without periradicular pathoses, were included. However, if the canals could not be dried, the tooth was not obturated in the first appointment and therefore was excluded from the data collection. Instrumentation was completed in a crown-down manner with NiTi rotary instruments or a combination of NiTi rotary and stainless steel hand filing. Patency was established and maintained when possible. Irrigants used during the procedures included 5.25% NaOCl and 17% EDTA.

Table 1 Studies evaluating healing of single-visit and multiple-visit root canal treatment

Study	Model	Cleaning and shaping technique	%NaOCl	%EDTA	Healing determination	#1V	%Success 1V	Intracanal medicament	#MV	%Success MV
Weiger *et al.* (2000)	Human	Hand instrumentation – step back	1	–	Clinical and radiographic	36	83.8	$CaOH_2$	31	70.9
Katebzadeh *et al.* (2000)	Dog	To ISO 45	–	–	Radiographic	24*	35.3	$CaOH_2$	24*	36.8
Trope *et al.* (1999)	Human	Not indicated	2.5	–	Radiographic	45	80.0	$CaOH_2$	31	81.0
Sjögren *et al.* (1997)	Human	Hand filing and ultrasonics	0.5	–	Clinical and radiographic	53	83.0	–	–	–
Leonardo† *et al.* (1995)	Dog	Hand instrumentation	0.5	–	Histologic	15*	20.0	–	–	–
			5.25 w/3% H_2O_2	14.3				$CaOH_2$	16*	81.2
Jurcak *et al.* (1993)	Human	Hand instrumentation	Not specified	Not specified	Clinical and radiographic	102	89.0	–	–	–
Pekruhn (1986)	Human	Hand instrumentation	2.5	–	Clinical and radiographic	925	94.8	–	–	–
Oliet (1983)	Human	Not indicated	5	–	Clinical and radiographic	153	89.0	Not specified	185	89.0
Rudner & Oliet (1981)	Human	Hand instrumentation	2–3 w/3% H_2O_2	Not specified	Clinical and radiographic	30	89.7	Not specified	74	91.1
Ashkenaz (1979)	Human	Hand instrumentation – step back	5.0	–	Clinical and radiographic	101	97.0	–	–	–
Soltanoff (1978)	Human	Hand instrumentation	–	–	Radiographic	80	85.0	Not specified	186	88.0

*Roots counted instead of teeth.

†Irrigants differ between treatment groups.

#1V, number of samples treated in one visit.

#MV, number of samples treated in multiple visits.

Working lengths were obtained primarily by apex locator; however, radiographic confirmation was used when necessary. Obturation was completed with warm vertical compaction using Kerr Pulp Canal Sealer Extended Working Time (Kerr USA, Romulus, MI, USA).

Only those patients who returned for re-examination appointments of 6 months or longer were included in the study unless further treatment of the tooth was initiated prior to this time, deeming these cases as failures. If the tooth was clinically and radiographically within normal limits (Strindberg 1956, Gutmann 1992; Table 2), the treatment was considered successful. If the tooth was symptomatic, provided no evidence of healing radiographically and required re-treatment, surgical intervention or extraction, the case was considered a failure. Statistical analysis was carried out using Chi-square tests and considered variations in failure rates based on gender, provider, tooth type, position and arch. For the data on age, a *t*-test was used to evaluate differences in failure rates. Significance was considered to be $P = 0.05$.

Results

The study comprised of 223 patients (147 females and 76 males; Table 3). Of the females, 128 treatments (87.1%) were successful and 19 treatments (12.9%) failed. The males had 71 (93.4%) success and 5 failures (6.6%). No statistically significant differences were found based on gender, even though the failure rate was two times as high in females compared to that in males. Ideally, if a higher percentage of recall evaluations had been obtained, the data might have reflected different outcomes.

Patients in the study ranged in age from 16 to 89 years. Of the 199 successful cases in the study, the mean age was 52 years (±15 years) as compared to the mean age of 51 years (±11 years) in the failure group. The data show almost equal ages between those that succeeded and those that failed (Table 4). Consequently, the *t*-test indicated no statistically significant differences in failure rates based upon age.

Further analysis looked at the effect of different operators on failure rates. Four clinicians completed the treatment with overall success of 89.2%. Individually, the success rates varied between operators from 81.8 to 95.2% (Table 5). Even though there were numerical differences between providers, there were no statistically significant differences found.

The remaining analyses compared differences in failure rates based upon tooth type and tooth position. Teeth were divided between mandibular and maxillary arches resulting in 111 maxillary and 112 mandibular teeth included in the analysis (Table 6). The results show that treatment in 100 (89.3%) maxillary and 99 (89.2%) mandibular teeth was successful. Therefore, this nearly even distribution showed equality in successful treatment of both maxillary and mandibular teeth.

With respect to type of tooth, 48 incisors, 65 premolars and 110 molars were evaluated; the success rates were 97.9, 86.2 and 87.3%, respectively. The rates amongst these groups were not significant ($P = 0.088$); however, the numerical trend showed that the incisors tended to have a much lower failure rate (Table 7).

In a similar comparison, the premolars and molars were combined into one 'posterior' grouping. When looking at the data this way, significant differences in failure rates were found between the groups. The anterior group had only one failure (2.1%) compared to the failure of the 23 posterior teeth (13.1%; Table 8).

Because of the possibility of a second canal in the mesiobuccal root of the maxillary first molar and the inherent difficulty in identifying it, these teeth were grouped together. Comparison was made with other molars and premolars grouped with anterior teeth (Table 9). There were 33 maxillary first molars included in the study. Of these, 28 (84.8%) were successful and 5 (15.2%) failed. When looking at all other molars as a group, 77 teeth were included. Of these, 68 (88.3%) succeeded and 9 (11.7%) were

Table 2 Guidelines for clinical and radiographic success (adapted from Gutmann 1992)

	Success	Questionable	Failure
Clinical	No tenderness to percussion or palpation	Sporadic vague symptomology, often not reproducible	Persistent subjective symptoms
	Normal mobility	Pressure sensation or feeling of fullness	Recurrent sinus tract or swelling
	No sinus tract or periodontal disease	Low-grade discomfort following percussion, palpation or chewing	Predictable discomfort to percussion or palpation
	Tooth function	Discomfort when pressure is applied by the tongue	Evidence of irreparable tooth fracture
	No signs of infection or swelling	Superimposed sinusitis with a focus on the treated tooth	Excessive mobility or progressive periodontal breakdown
	No evidence of subjective discomfort	Occasional need for analgesics to relieve minimal discomfort	Inability to function on the tooth
Radiographic	Normal to slightly thickened periodontal ligament space (<1 mm)	Increased periodontal ligament space (>1 mm and <2 mm)	Increased width of periodontal ligament space (>2 mm)
	Elimination of previous rarefaction	Stationary rarefaction or slight repair evident	Lack of osseous repair within rarefaction or increased rarefaction
	Normal lamina dura in relation to adjacent teeth	Increased lamina dura in relation to adjacent teeth	Lack of new lamina dura
	No evidence of resorption	Evidence of resorption	Presence of osseous rarefactions in periradicular areas where previously none existed
	Dense, three-dimensional obturation of canal space extending to cementum–dentin junction (1 mm from apex)	Voids in obturation density	Visible, patent canal space – unfilled or significant voids in obturation
		Extension of filling material beyond anatomic apex	Excessive overextension with voids in apical third
			Active resorption coupled with other radiographic signs of failure

Table 3 Success rate by gender

	F	M	Total
Success			
n	128	71	199
%	87.1	93.4	89.2
Failure			
n	19	5	24
%	12.9	6.6	10.8
Total	147	76	223

$P = 0.147$.

Table 4 Success rate by age

Status	*N*	Mean	SD	SEM
Success	199	52.49	15.270	1.082
Failure	24	51.46	10.879	2.221

$P = 0.749$.

Table 5 Success rate by provider

	I	II	III	IV	Total
Success					
n	62	9	48	80	199
%	82.7	81.8	90.6	95.2	89.2
Failure					
n	13	2	5	4	24
%	17.3	18.2	9.4	4.8	10.8
Total	75	11	53	84	223

$P = 0.064$.

considered failures. The group of incisors and premolars had 113 teeth of which 103 (91.2%) succeeded and 10 (8.8%) failed. In addition, the failure rate for maxillary first molars was compared to that for all other teeth (Table 10). Although the failure rate for maxillary first molars was higher (15.2%) than all other teeth (10.0%), there were no statistically significant differences found either here or in the previous analysis.

Table 6 Success rate by arch

	Mandibular	Maxillary	Total
Success			
n	100	99	199
%	89.3	89.2	89.2
Failure			
n	12	12	24
%	10.7	10.8	10.8
Total	112	111	223

$P = 0.981$.

Table 7 Success rate by tooth type

	Incisor	Premolar	Molar	Total
Success				
n	47	56	96	199
%	97.9	86.2	87.3	89.2
Failure				
n	1	9	14	24
%	2.1	13.8	12.7	10.8
Total	48	65	110	223

$P = 0.088$.

Table 8 Success rate differences between anterior and posterior teeth

	Anterior	Posterior	Total
Success			
n	47	152	199
%	97.9	86.9	89.2
Failure			
n	1	23	24
%	2.1	13.1	10.8
Total	48	175	223

$P = 0.029$.

Table 9 Success rate of maxillary first molars compared to molars and premolars and incisors

	I/PM	M	MFM	Total
Success				
n	103	68	28	199
%	91.2	88.3	84.8	89.2
Failure				
n	10	9	5	24
%	8.8	11.7	15.2	10.8
Total	113	77	33	223

I/PM, incisors and premolars; M, molars; MFM, maxillary first molars.
$P = 0.560$.

Table 10 Success rate of maxillary first molars compared to all other teeth

	Other teeth	MFM	Total
Success			
n	171	28	199
%	90.0	84.8	89.2
Failure			
n	19	5	24
%	10.0	15.2	10.8
Total	190	33	223

$P = 0.02$.

Table 11 Studies identifying two canal systems in mesiobuccal root of maxillary first molars

Study	Year	*In vitro*	Two-canal systems (%)
Kulild & Peters	1990	v	95*
Thomas *et al.*	1993	v	74
Fogel *et al.*	1994	–	71
Pomeranz & Fishelberg	1974	v	69*
Seidberg *et al.*	1973	v	62
Pineda	1973	v	59
Vertucci	1984	v	55
Weine	1969	v	52
Weller & Hartwell	1989		39

*Second maxillary molars were included.

Discussion

Initially, a success/failure study was attempted prospectively with more discrete criteria for inclusion and variable control. Comparison was to be made between single-visit treatment of teeth with periradicular radiolucencies and teeth being re-treated in a single visit with radiolucencies present. The main objective was to evaluate patients treated in busy private practices with clinicians who had been practising for more than 5 years using rotary instruments with a crown-down technique (Goerig *et al*. 1982, Morgan & Montgomery 1984). This would eliminate bias from lack of experience. However, in the specialized private practices selected, patients originally included in the study did not readily return for their 1-year re-examination visits. This may have occurred for a number of reasons, including lack of pain, returning to the referring dentist if problems occurred or because of patient re-location. Patients were contacted by telephone up to five times to schedule re-examination appointments; however, the return rate was not acceptable (17.8%). Interestingly, 1 year after treatment, several patients who were contacted did not remember receiving root canal treatment. Because of the low 1-year re-examination rate of those included in this projected prospective clinical study, the decision was made to collect data retrospectively. This new approach afforded larger numbers of patients treated in one visit; however, different impediments were encountered.

The endodontic practice involved in the retrospective study upgraded to a new computer program that was implemented in June 2000. Data on patients that were seen in previous years were consistently accessible only through the use of the discontinued system, as well as charts that were archived. Because of this, a few limitations were experienced. As is the case in retrospectively designed studies, time periods available for data collection were limited by the lack of records available from 1995 and earlier, as well as leaving enough time after treatment for potential healing or failure to heal. To adapt to these limitations, a 30-month period was agreed upon to increase the sample size for re-examination. In evaluating the amount of time necessary before healing can be reasonably established, Ørstavik (1996) compared healing rates clinically and radiographically in teeth with and without periradicular radiolucencies. Radiographic evidence of healing, as well as newly forming radiolucencies, had a peak occurrence at the 1-year re-examination appointment. However, some radiolucencies did not show total healing until 4 years after treatment. Weiger *et al*. (2000) also showed increased success at 5 years compared to a 1-year follow-up. Therefore, because only 2 and 1.5 years were available for retrospective evaluation, reported success rates may be conservative.

In assessing treatment outcomes by gender (Table 3), females had a higher failure rate (12.9%) compared to males (6.6%). These differences, however, were not statistically significant. Because there were 147 females and only 76 males in the study, it would appear

that females were more conscientious about returning for their follow-up examinations than males; however, this may not be accurate. Of the 768 cases of single-visit root canal treatment, 505 were females and 263 were males. This is almost a 2 : 1 ratio of those that were initially treated, which is similar to the re-examination rate. These findings are similar to those by Smith *et al*. (1993), who also found more females to present for root canal treatment, but a lower percentage of success in women than in men. However, Soikkonen (1995) took radiographs of patients and found more periradicular radiolucencies present in men than in women. These findings, however, were seen in teeth with root canal treatment, as well as in those patients who had never been treated endodontically.

The age of the patient was evaluated because of the inherent difficulties encountered in teeth in which canals, through time, continue to narrow down as a result of deposition of mineralized tissue (Gustafson 1950, Dummer *et al*. 1984), as well as the decrease in healing ability of elderly patients (Williams & Hadler 1983). Despite these physiological differences, the age of the patient did not appear to affect the outcome of treatment (Table 4). One would speculate that the successful group would have a lower mean age than those that failed. However, this was not the case. With the mean ages of the two groups only slightly more than a year apart, the success rate in this study was not dependent on the age of the patient.

Accumulation of chronic illnesses is the major factor in healing delays of the elderly (Williams & Hadler 1983). The patients' systemic health status was not able to be collected retrospectively; however, all patients were treated in a private practice setting, which would include mostly healthy patients and those with minor health concerns. This could explain the similarities in healing as related to age.

Because four clinicians completed the treatment, evaluation of success rates were made by these providers (Table 5). The clinicians had a wide range of experience in restorative dentistry and practice limited to endodontics. No statistically significant differences were found amongst the providers; however, numerical trends were observed. In fact, success rates varied from 81.8 to 95.2%. Provider II had fewer cases included in the study because of limited clinic time (11 patients in total), which could explain his higher failure rate. Furthermore, case selection differences could explain differences in the numerical trends. Because there was no statistically significant difference, these success rates could have occurred merely by chance. The overall success rate was 89.2%, which is similar to that reported by Rudner & Oliet (1981), Oliet (1983) and Jurcak *et al*. (1993), all of which were single-visit success rates. Of the therapy completed in more than one visit, this success rate compares closely to that reported by Oliet & Sorin (1969), Oliet (1983) and Pekruhn (1986).

Treatment considerations change depending on the complexity of each tooth. Some of these include anatomical variations as seen radiographically, clinically and those understood from studying similarities in tooth type, as well as number of canals and/or roots (Pineda & Kuttler 1972, Benjamin & Dowson 1974, Dummer *et al*. 1984, Vertucci 1984). Therefore, the data were evaluated in several different ways to compare the success rates by position and type of tooth.

The first analysis differentiated success rates between maxillary and mandibular teeth (Table 6). The groups were divided evenly having 112 mandibular and 111 maxillary teeth evaluated. Along with this even distribution came similar success rates that were within one-tenth of a percentage point (89.3% vs. 89.2%). This shows similar rates of success in mandibular and maxillary teeth in this study. These results correspond to those found by Pekruhn (1986) in that the failure rate of all maxillary teeth was 5.4% compared to 5.0% in mandibular teeth, even though the ratio of maxillary versus mandibular teeth was around 2 : 1 (607 maxillary, 318 mandibular).

Another comparison was by tooth type. Each tooth type, whether they were mandibular or maxillary, was classified into three groups: incisors, premolars and molars (Table 7). As

only one incisor of the 48 included in the study failed, the success rate was numerically higher (97.9%) than the premolars and molars (86.2 and 87.3%, respectively). The *P*-value was close to achieving statistical significance ($P = 0.088$), which may or may not have been attained if the sample size available had been larger. Rudner & Oliet (1981) divided the data by tooth type and found slight increases in success when going from molars to anterior teeth (85.7% in molars, 90.4% in premolars and 91.8% in anterior teeth). Sjögren *et al.* (1997) and Ashkenaz (1979) only included single-rooted teeth in their studies and found success rates of 83.0 and 97.0%, respectively.

When comparing anterior teeth to premolars and molars in one 'posterior teeth' group (Table 8), the Chi-square analysis showed statistical significance ($P = 0.029$). The difference is most likely seen because of anatomical complexities of posterior teeth compared to the single-rooted canal systems of anterior teeth. However, Rudner & Oliet (1981) found that group similarity when teeth were divided in this manner (87.7% success in posterior teeth as opposed to 91.8% in anterior teeth).

In another tooth-type comparison, maxillary first molars were evaluated against other molars (Table 9). The reason for distinguishing this tooth type is because of the difficulty in identifying, negotiating and treating the mesiopalatal canal. The incidence of this canal has been studied with varying results. Some of these studies are summarized in Table 11. Statistical significance was seen when maxillary first molars were compared to all other teeth (Table 10), with the difference in success rates ranging from 84.8% (seen in teeth 16 and 26) to 90.0% in all other teeth grouped together ($P = 0.029$). This may be because of the management of the mesiopalatal canal clinically.

Conclusions

Evidence obtained by evaluating clinical data retrospectively is not as strong as evidence obtained from controlled, prospective, randomized clinical trials. This is why a prospective study was attempted initially. However, patient compliance issues, as well as available resources, precluded this original research design. Further study of single-visit treatment is still necessary with emphasis on new instrumentation and obturation techniques, as well as chemical irrigants used. Furthermore, issues of smear layer removal, patency filing and the exclusive use of electronic apex locaters could be evaluated in addition to the apical termination of cleaning and shaping, and the presence or absence of extruded obturation materials, including product types. Factors that would provide evidence-based information include: (i) prospectively designed studies; (ii) large sample sizes; (iii) detailed treatment parameters; (iv) clinical and radiographic healing determination with stringent, consistent and reproducible parameters; and (v) long-term re-examination rates with high levels of patient compliance.

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