A Retrospective Study of Endodontic Treatment Outcome between Nickel-Titanium Rotary and Stainless Steel Hand Filing Techniques

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Abstract

Aim: The purpose of this study was to compare the periapical healing of molar root canal treatment using two instrumentation techniques. **Methods:** A total of 225 maxillary and mandibular first and second permanent molars endodontically treated by undergraduate or postgraduate students were randomly selected from a computerized hospital database of which 110 molars had been prepared using a hybrid rotary technique with nickel-titanium instruments (group NR) and 115 with hand stainless steel files (group HF). Patients were recalled and the teeth were examined both clinically and radiographically for signs of periapical inflammation. **Results:** Some 19% and 39% of teeth in the NR and HF group, respectively, were judged to have some form of procedural errors. A higher rate of periapical healing was noted for NR (77%) than the HF group (60%) ($p < 0.05$). Factors contributing favorably to treatment outcome included the use of rotary technique, maxillary molar, experienced operator, and absence of preoperative radiolucent lesion. **Conclusion:** There was a higher incidence of procedural errors and a lower success rate for primary root canal treatment of teeth prepared with stainless steel files compared with the use of NiTi instruments in a continuous reaming action. *(J Endod 2009;35:938–943)*

Key Words

Apical periodontitis, complications, failure, ledging, nickel-titanium instruments, periapical healing, procedural errors, success

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Nickel-titanium alloy (NiTi) has been introduced for the manufacture of endodontic instrument since late 1980s (1). Compared with their stainless steel counterpart, NiTi files are much more flexible and are more resistant to torsional fracture (2). The Lightspeed (LightSpeed, San Antonio, TX) and the ProFile rotary instrument (Dentsply Tulsa Dental, Tulsa, OK) are the first NiTi systems available commercially in early 1990s. Both of them have a similar cross-sectional design that comprises three evenly spaced U-shaped flutes and "radial lands" and a non-cutting pilot tip. The former brand has a parallel shaft and a short cutting head, akin to a Gates-Glidden bur, whereas the latter looks like a traditional file with a spiraling cutting part of 16 mm in length. Other brands with various cross-sectional designs have since been marketed. Nowadays, an increasing number of clinicians use one brand or another for preparing the root canals. Many studies have shown that engine-driven NiTi rotary instruments are able to produce better centered canals with lesser amount of transportation than manually operated stainless steel files (3–7). However, instrument breakage has been a concern of many of those using or contemplating the use of NiTi engine-files; the lack of tactile feedback is also a concern of some others. This has led (in part) to the introduction of a hand-operated version of some NiTi rotary instruments.

The combined use of ProFile engine files and a hand-operated NiTi instrument (Thermafil Verifier [Dentsply Maillefer, Ballaigues, Switzerland]; this instrument has an identical design as ProFile but comes with a handle and thus may be operated manually in a continuous reaming motion) has been proposed and taught in a dental teaching hospital. This hybrid technique has been compared with the use of engine-driven K3 (SybronEndo, Orange, CA), ProTaper (Dentsply Maillefer), and Hero 642 (Micro-Mega, Besançon, France) in a laboratory study. It was found that the ProFile and Thermafil Verifier combination produced a canal shape comparable to and sometimes better than other systems tested and should be suitable for clinical use (8).

Although studies have shown the superiority of rotary over manual instrumentation in terms of the shaping ability and efficiency in a clinical setting (2, 9, 10), there are few reports of the effect of NiTi rotary instrumentation on the treatment outcome. One study showed that periapical healing of teeth treated by way of manual instrumentation (stainless steel K files) was comparable to that using ProFile (engine files); the result was based on a total of 66 patients, a sample size that might be too small to show a difference (11). Another report indicated that the overall success rate of endodontic treatment was about 86% with the use of rotary instruments (ProFile vs GT Rotary [Dentsply Tulsa] vs Lightspeed) with no significant difference between brands (12); however, a group of manual instrumentation was not included for comparison. The aim of this cohort study was to evaluate the periapical healing and the incidence of procedural errors of molar teeth treated endodontically using a rotary technique as compared with manual preparation with stainless steel hand files.

Materials and Methods

In a dental teaching hospital in which the great majority of dental treatments are provided by dental undergraduate or postgraduate students, there have been some changes in the root canal instrumentation technique taught throughout the years. Before the year 2000, students were taught to clean and shape root canals using only hand files.

TABLE 1. A Hybrid Rotary Technique Based on a Combination of NiTi Engine Files* and Hand NiTi Instruments (Used in a Continuous Reaming Motion)

1. Estimate the working length from radiographs and check patency of canal(s) using no. 10 or 15 hand files to within 1 to 2 mm of this estimated length
2. ProFile orifice shaper (OS) #3, OS #2, then OS #1 to the beginning of curvature, or to where resistance is felt, gradually advancing deeper with each file
3. Working length (WL, being 1-mm short of the radiographic apex) determination with a no. 15 file in place and a measurement radiograph
4. Canal preparation using ProFile in the following sequence:
   ProFile 0.06 taper, no. 15 engine file at WL–1.0 mm (or to resistance)
   Thermafil Verifier no. 20 (hand) at WL
   ProFile 0.06 taper, no. 20 engine file at WL
   Thermafil Verifier no. 25 (hand) at WL
   ProFile 0.06 taper, no. 25 engine file at WL
   Thermafil Verifier no. 30 (hand) at WL
   ProFile 0.06 taper, no. 30 engine file at WL
   Thermafil Verifier no. 35 (hand) at WL
   (ProFile 0.06 taper, no. 35 engine-file at WL, for relatively short root canals, say, of not more than 18 mm in length, or canals with a large initial size such as the maxillary central incisors)
5. Recapitulation using a no. 15 hand file in between each irrigant of the following final rinse sequence: NaOCl (1%-2.5% solution), EDTA (17%), and then NaOCl

*(1) Only gentle pressure was applied with irrigation (2∼3 mL of NaOCl) after each instrument at all times; and (2) driven by an electric motor (Tecnika; ATR, Milan, Italy): 150 to 300 rpm (the greater the curvature, the lower the rotation rate) at the manufacturer's recommended torque setting.

This was done with the step-back technique (13) before 1996 and then with the step-down technique, as was described by Goerig et al (14) and is considered a modification (of the sequence) of the step-back technique, from 1996 to 2000. Stainless steel hand files (Flexofile, Dentsply Maillefer) were precurved and used in a filing motion for both techniques. Since the autumn of 2000, rotary instrumentation using NiTi files was introduced to the curriculum. Between 2000 and 2005, a rotary technique using a combination of ProFile (0.06 tapered) engine files and Thermafil Verifiers was taught (Table 1). The Verifier has the same design of a ProFile 0.04 tapered engine file but is fitted with a handle, instead of a latch-type grip; it was operated in a continuous reaming motion. All teeth were obturated using lateral or vertical compaction of gutta-percha with an epoxy resin–based sealer (AH26 or AH Plus; Dentsply Caulk, Milford, DE).

From the computerized hospital database, there were 1,786 primary (ie, first-time treatment, all retreatments excluded) nonsurgical root canal treatments completed for both maxillary and mandibular first and second permanent molars from 1993 to 1999. Of these, 117 cases were randomly selected and constituted the group for which root canal instrumentation was performed by hand with a filing technique using stainless steel instruments (group HF). From 2001 to 2005, there were 1,448 primary endodontic treatments completed for the maxillary and mandibular first and second molars. A random selection of 112 records were retrieved and checked to confirm that root canal preparation had indeed been performed with the hybrid rotary technique using NiTi (continuous reaming by hand or engine driven) instruments (group NR). All treatment records were examined in detail. Demographic data and information related to the treatment were obtained. Five types of procedural errors, if any, were identified by noting the entries in the record and from the radiographic appearance of the root canal fillings: ledging, perforation (lateral or strip perforation), apical transportation, stripping (but not perforated), and fractured instrument. Any attempt by the operator at that time to correct the error(s) before obturation was also noted.

All selected patients were then invited to return for a recall during which clinical and radiographic (paralleling technique) examination of the tooth were performed. Radiographs were evaluated by a precalibrated examiner. The treatment outcome was classified into three categories: (1) "favorable," when there were no signs or symptoms associated with the tooth and no periapical rarefaction (or with an obvious diminishing periapical rarefaction if the observation time was less than 4 years duration); (2) "uncertain," when a preexisting periapical rarefaction showed no discernible change in size (only for those with an observational period shorter than 4 years that remained asymptomatic), and (3) "failure to heal," when the tooth was associated with a newly developed or an enlarging periapical lesion or with a radiolucent area of any size for 4 years or more after treatment. The treatment was also deemed to be a failure if the tooth was symptomatic at recall, regardless of the radiographic appearance.

All data, including intraoperative covariables, treatment outcome, and the incidence of procedural errors were entered into a spreadsheet and analyzed in software (SPSS Version 16.0; SPSS Inc, Chicago, IL). The associations of both the healing outcome and the (incidence of) procedural errors with various factors for the two instrumentation groups were first examined in a univariate test (Mann-Whitney or chi-square where appropriate). Covariables attaining an arbitrary threshold of $p = 0.25$ were entered into a multiple logistic regression analysis in which stepwise backward elimination of those factors that failed to attain statistical significance ($\alpha = 0.05$) and/or with the highest p value was performed. Potential interaction between various factors was also examined separately using a nonparametric (chi-square or Fisher exact) test.

Results

A total of 229 molars in 216 patients were examined; all of them had received treatment from a dental undergraduate or postgraduate student. There were two extraction cases in each group (NR and HF) because of fracture of the tooth or root. These four cases were excluded in the subsequent analysis. Of all 225 teeth analyzed, totally 24% ($n = 53$) were deemed to be a failure to heal, whereas 68% ($n = 154$) showed complete resolution or definitive sign of healing (Tables 2 and 3). The NR group was associated with a significantly higher rate of favorable/complete healing (77% vs 60%, $p < 0.05$, chi-square test) and lesser amount of procedural errors (overall incidence 19% vs 39%, $p < 0.05$, Mann-Whitney test) than the HF group (Tables 2 and 3). The two instrumentation groups differed significantly from each other in the amount of (un)successful healing only for teeth with a preoperative periapical radiolucent area, but the difference was not significant for those without a preexisting lesion (Table 2). Cases with a preoperative periapical radiolucency and treated with hand instrumentation showed the lowest success rate. There was some confounding between the operator and both the dental arch and instrumentation method for their effect on treatment outcome. Undergraduate students performed significantly better in the maxillary than mandibular arch (healing rate 80% vs 63%, $p < 0.05$) and when using the hybrid rotary/reaming technique (81% compared with 55% for hand filing, $p < 0.05$) (Table 4). Postgraduate students (ie, endodontic residents) showed a similar performance in both arches ($p > 0.05$), but with a tendency for a higher healing rate when rotary instrumentation was used (that barely reached a significant level, Table 4).

NiTi instruments generally produced significantly fewer procedural errors than stainless steel hand files (Table 3). The distribution of the various forms of procedural error in either group was not normally distributed, and, thus, the Mann-Whitney test was used to compare their incidence between groups. There was a significant difference between the HF and NR group in the amount of ledging and

TABLE 2. Healing Outcome for the Two Instrumentation Groups: Distribution of Teeth According to Various Covariables

Covariable	Subgroups	NR group (% of subtotal)				HF group (% of subtotal)			
		Favorable	Uncertain	Failure	Subtotal	Favorable	Uncertain	Failure	Subtotal
Gender	Male	27 (81.8)	3 (9.0)	3 (9.0)	33	23 (62.1)	2 (5.4)	12 (32.4)	37
	Female	58 (75.3)	7 (9.0)	12 (15.5)	77	46 (58.9)	6 (7.6)	26 (33.3)	78
Dental arch	Maxillary	39 (86.6)	3 (6.6)	3 (6.6)	45	31 (73.8)	1 (2.4)	10 (23.8)	42
	Mandibular	46 (70.7)	7 (10.7)	12 (18.4)	65	38 (52.0)	7 (9.5)	28 (38.3)	73
Operator	Undergraduate	65 (73.0)	9 (10.1)	15 (16.8)	89	36 (50.7)	6 (8.4)	29 (40.8)	71
	Postgraduate	20 (95.2)	1 (4.7)	0 (0)	21	33 (75.0)	2 (4.5)	9 (20.4)	44
Preoperative radiolucency	Presence	63 (74.1)	10 (11.7)	12 (14.1)	85	46 (52.8)	8 (9.1)	33 (37.9)	87
	Absence	22 (88.0)	0 (0)	3 (12.0)	25	23 (82.1)	0 (0)	5 (17.8)	28
Post-endodontic restoration	Occlusal coverage	61 (80.2)	6 (7.8)	9 (11.8)	76	43 (65.1)	2 (3.0)	21 (31.8)	66
	Amalgam only	16 (64.0)	4 (16.0)	5 (20.0)	25	18 (54.5)	5 (15.1)	10 (30.3)	33
	Others	8 (88.8)	0 (0)	1 (11.1)	9	8 (50.0)	1 (6.2)	7 (43.7)	16
Age (mean ± SD)		41.5 ± 13.7	51.8 ± 14.7	47.6 ± 12.4	43.3 ± 13.9	39.4 ± 15.4	43.3 ± 8.2	41.9 ± 14.3	40.5 ± 14.7
Time of recall (mean ± SD)		21.9 ± 14.3	17.6 ± 12.1	28.2 ± 15.8	22.3 ± 14.5	28.8 ± 21.4	21.9 ± 15.2	38.7 ± 24.8	31.6 ± 22.7
Total		85 (77.3)	10 (9.1)	15 (13.6)	110	69 (60.0)	8 (7.0)	38 (33.0)	115

SD, standard deviation.

perforation produced ($p < 0.05$) but not for stripping, apical transportation, or instrument separation. When the two forms of procedural error (ledging and perforation) were entered into the stepwise logistic regression analysis, only "ledging" was found to have a significant negative impact on the treatment outcome (odds ratio = 2.0 for a higher chance of failure) (Table 5). Other factors that had a significant influence on the treatment outcome included the time of recall (greater chance of failure for longer observation period), operator (with postgraduate producing a greater amount of favorable outcome than undergraduate students), dental arch (reduced chance of failure for maxillary molars), instrumentation method (rotary instrumentation being more favorable), and the presence of a preoperative radiolucent lesion (being more prone to failure) (Table 5).

Discussion

There have been various sets of criteria and terms used to describe the outcome of root canal treatment in the past. Traditionally, "success" and "failure" had been used to describe the outcome of an endodontic treatment, with an "uncertain" group when the radiographic evidence of healing is inconclusive. Alternatively, the terms "healed," "healing," and "diseased" have been used, which describe the actual observation of the disease progression (15). Both sets of nomenclature are based on the radiographic appearance of the periapex. The "uncertain" group in the former set of criteria, if unresolved after a certain period, would be deemed a failure or "diseased" in the latter nomenclature (15). In this study, the teeth were also examined clinically, and the presence of any symptoms was considered as a failure of the periapical tissue to heal, regardless of the radiographic status. A set of published guidelines has suggested that to qualify an endodontically treated tooth for success periapical healing must have been completed within 4 years after root canal treatment (16). Arguably, a 4-year cutoff period may not be appropriate for all cases because healing could still continue beyond that period (17). Thus, a study using such strict criteria might have overstated the failure rate. On the other hand, as we have classified some diminishing (in size) radiolucent areas as a "favorable" outcome, it is possible for our result to understate the amount of failures. In fact, the result of logistic regression indicated a slight increase in the chance of failure (odds ratio = 1.03) for lengthier recall periods. A similar trend of a declining survival has been reported for the initial period, up to about 5 years, after nonsurgical root canal treatment (18, 19).

Many studies have shown that NiTi rotary instruments are superior to stainless steel hand files for shaping the root canal space (2–7, 9, 10). The advantages of NiTi rotary instrumentation include the maintenance of original shape and curvature of the canal (4–7, 10), reduced likelihood of procedural errors (5, 9, 10), shortened treatment time (3, 5, 9), and an ideal tapering canal form for obturation (9). However, there has been no randomized clinical trial to compare the effect of rotary versus manual instrumentation on the outcome of nonsurgical root canal treatment; such a study would take quite some time to produce a meaningful result. In the literature, a prospective study based on a limited number of patients suggested that the use of either stainless steel hand files or rotary instruments (ProFile) would not significantly affect the treatment outcome in a regression model (11). Our result from a larger sample indicated that the instrumentation method carries a significant effect; the use of NiTi instruments in a continuous reaming action is associated with a higher incidence of periapical healing. Indeed, the chance of success was about 3.8-fold that of hand instrumentation using stainless steel files by applying a stepwise backward logistic regression analysis. The reduced chance of success is likely to be related to a greater amount of aberrant canal

TABLE 3. Healing Outcome for the Two Instrumentation Groups: Incidence of Procedural Errors*

	NR group (SD)				HF group (SD)			
Type of error	Favorable	Uncertain	Failure	Subtotal	Favorable	Uncertain	Failure	Subtotal
Ledging†	0.14 (0.35)	0.10 (0.32)	0.20 (0.41)	0.15 (0.35)	0.22 (0.42)	0.63 (0.52)	0.50 (0.51)	0.34 (0.48)
Stripping	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.12)	0.00 (0.00)	0.00 (0.00)	0.01 (0.09)
Apical transportation	0.02 (0.15)	0.00 (0.00)	0.07 (0.26)	0.03 (0.16)	0.01 (0.12)	0.00 (0.00)	0.03 (0.16)	0.02 (0.13)
Perforation†	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.12)	0.00 (0.00)	0.08 (0.27)	0.03 (0.18)
Fractured instruments	0.01 (0.11)	0.10 (0.32)	0.07 (0.26)	0.03 (0.16)	0.01 (0.12)	0.00 (0.00)	0.00 (0.00)	0.01 (0.09)
Overall			*n* = 21 (or 19.1%) out of 110				*n* = 45 (or 39.1%) out of 115	

NR, hybrid rotary technique with nickel-titanium instruments; HF, hand stainless steel files.

*The figures are normalized and given as the amount of occurrence per tooth, except stated otherwise.

†Significantly different between the NR and HF group for this procedural error ($p < 0.05$, Mann-Whitney test).

shapes produced by manual (filing action) instrumentation. Ledge formation was the most prevalent procedural error for both groups, but this affected significantly more cases in the HF than the NR group (Table 3). The presence of ledges, a form of canal obstruction, if not corrected and the original canal not instrumented would lower the rate of success (20, 21). Indeed, any intraoperative complications could have a significant negative impact on the treatment outcome (22, 23). There were significantly more cases of perforation in the HF group, with a corresponding lower success rate compared with the use of NiTi rotary/reaming technique. However, the actual incidence of perforation was too low to show a significant effect in the logistic regression model. Similarly, the amounts of stripping, apical transportation, and fractured instrument were also too small for the statistical test to show an association with the treatment outcome. The presence of a fractured file fragment in the canal did not seem to have an effect on periapical healing, which results is in agreement with the findings of other case-controlled studies (24, 25).

Only maxillary and mandibular molars were selected as the sample for this study because previous reports have indicated that this group of teeth are most likely to fail after primary root canal treatment (18, 19), especially when strict criteria are adopted and the whole tooth (instead of individual roots) is regarded as the unit of measure (23). Any means to improve the treatment outcome for molars is likely to benefit other tooth types as well. Considered separately, a significantly higher healing rate was observed for maxillary than mandibular molars (81% vs 61%, odds ratio = 0.31 for a lower chance of failure in the maxilla). The reduced success rate for mandibular molars may partly be explained by their complex anatomy, especially for the second molar. The C-shaped root canal system is a common occurrence among the local population (26); the incidence was estimated to be about 30% or higher (27). This canal anatomy is a challenge to effective endodontic therapy (28). Unfortunately, the presence of a C-shaped root canal anatomy was not routinely entered in the treatment record at that time, and, hence, the exact number was not available. Clinical accessibility, especially for the mesial canals of lower molars, might be another factor leading to a reduced success rate.

Teeth with preoperative periapical radiolucency carry a significantly higher chance of failure to heal than those without a preexisting lesion. This corroborates the findings of many other studies (15, 19, 21–23, 29, 30), suggesting that endodontic treatment may be less effective when the root canal system is infected. In the presence of an established periapical lesion, microorganisms are usually found within the root canal space, extending close to the apical foramen and often penetrating into the dentinal tubules (31, 32). It is difficult to rid all microbes from the root canal space (33), especially when canal aberrations or procedural errors were present. In addition, a filing motion is prone to push, or even extrude debris apically, much more so than the use of a reaming or rotary technique (34, 35). Debris present at or near the apical foramen, if infected, could have a negative influence on healing (33, 36, 37). This would explain the higher rate of failure associated with teeth with preoperative periapical radiolucent lesion that were treated with a hand-filing technique when compared with rotary instrumentation. In contrary, periapical healing was not affected by the instrumentation method when a preoperative radiolucent lesion was absent (NR 88% vs HF 82%), probably because of a lesser extent of bacterial colonization or less diversity of species present in the pulp canal (15, 23). The collective success rate for

TABLE 4. Comparison of Healing Outcome of Treatment Performed by Different Operators

		*Healing outcome (% of subtotal, *n*)			*Healing outcome (% of subtotal, *n*)	
Operator	Teeth	Favorable	Failure	Instruments used	Favorable	Failure
Undergraduate (*n* = 160)	Upper molars (*n* = 58)	44 (80.0)	11 (20.0)	NR (*n* = 89)	65 (81.2)	15 (18.8)
	Lower molars (*n* = 102)	57 (63.3)	33 (36.7)	HF (*n* = 71)	36 (55.4)	29 (44.6)
	Total	97 (60.6)	44 (27.5)	Total	121 (63.1)	44 (27.5)
p value of Fisher exact for 2 × 2 table		0.041			0.001	
Postgraduate (*n* = 65)	Upper molars (*n* = 29)	26 (92.9)	2 (7.1)	NR (*n* = 21)	20 (100)	0 (0.0)
	Lower molars (*n* = 36)	27 (79.4)	7 (20.6)	HF (*n* = 44)	33 (78.6)	9 (21.4)
	Total	53 (81.5)	9 (13.8)	Total	53 (81.5)	9 (13.8)
p value of Fisher exact for 2 × 2 table		0.166			0.047	

*The column for "Uncertain" healing was excluded from this table and its value not considered in the Fisher exact test.

TABLE 5. Factors Showing a Significant Effect on the Healing Outcome ($p < 0.05$) After Backward Stepwise Logistic Regression Analysis (Listed in Ascending Order of the Odds Ratio*)

Covariables	Reference group	Test group	B	SE	Wald	*df*	Sig. (p value)	Odds ratio*	95% CI for the Odds Ratio
Instrumentation method	Hand-files	Rotary/reaming	−1.367	0.437	9.796	1	0.002	0.255	0.108–0.600
Dental arch	Mandible	Maxilla	−1.189	0.438	7.380	1	0.007	0.305	0.129–0.718
Time of recall	Date of obturation	Period after obturation	0.032	0.010	10.372	1	0.001	1.032	1.012–1.052
Ledging	No ledging	Ledge present	0.677	0.266	6.461	1	0.011	1.968	1.168–3.317
Operator	Postgraduate	Undergraduate	1.558	0.510	9.351	1	0.002	4.750	1.750–12.895
Preoperative radiolucency	No lesion	With preoperative lesion	1.639	0.540	9.202	1	0.002	5.148	1.786–14.842

CI, confidence interval; SE, standard error.

*Odds ratio = Exp(B); when its value is greater than 1, that implies a higher chance for the test group to FAIL when compared with the reference group.

teeth without preoperative area was 85% (both instrumentation groups combined), a figure that falls within the reported range using strict radiographic criteria (23). By combining the use of engine-driven and hand-operated NiTi instruments in a hybrid rotary technique (Table 1), the relatively inexperienced, undergraduate dental students managed a success rate of 81% (excluding uncertain healing, Table 4) for maxillary molars (but less well in the mandibular arch); the authors regarded this rate as commendable. It appeared that this hybrid NiTi rotary/hand-reaming technique could be a suitable method for use by inexperienced operators (who have been given appropriate instructions). Endodontic residents generally produced a more favorable outcome than the undergraduates, regardless of the instrumentation technique used, which result is more or less expected for their clinical skill level.

This study is a retrospective cohort study in which there were some uncontrolled variables, such as the operator skill and type and function of the final restoration. Radiographic interpretation can also be a source of errors (38). The instrumentation technique used was not the same as the one recommended by the manufacturer. Instead, a continuous reaming motion was used for a hand-operated NiTi instrument (Thermafil Verifier). Although this may be regarded as a ProFile 0.04 engine file used in an extremely low rotation rate, our results here may only be applicable to the hybrid technique described. Admittedly, a randomized controlled clinical trial would be ideal for comparing the effect of the rotary versus manual instrumentation and, perhaps, the difference among various brands of rotary instrument on the treatment outcome. Nonetheless, an association between rotary (continuous reaming) instrumentation and a lower incidence of procedural errors as well as a better treatment outcome is clearly shown for NiTi instruments. Within the limitation of this study, we would conclude that NiTi instruments should be the choice for preparing root canals in primary endodontic treatment, especially for inexperienced operator and for teeth with preoperative radiolucent lesions.

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