# An evidence-based analysis of the use of manual and rotary instrumentation in endodontic treatment

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**Abstract**

This paper is a systematic review of the literature comparing the use of rotary instruments and hand files pertaining to the efficacy of shaping and cleaning of root canals. Three keywords, namely, hand files, rotary files and endodontics were chosen to conduct searches on Ovid Medline, PubMed, Cochrane Library and the Journal of Endodontics. Dr. K. Roth, an endodontist at the University of Toronto and Dentsply Tulsa Dental Specialties were consulted to gain further insight on this topic. A total of 174 articles were obtained and using the inclusion and exclusion criteria, three articles were selected which are evaluated below. Schafer and Zapke (2000) concluded that manual files and rotary instruments yielded an equivalent degree of cleanliness; however, when shaping the canals, the best results were obtained with rotary instruments ($p < 0.05$). Tan and Messer (2002) concluded that the use of rotary instruments allowed for cleaner canals, as well as less apical transportation and thus, less deviation from initial canal curvature ($p < 0.05$). The study by Schafer et al. (2004), a rare clinical study, demonstrated that rotary instrumentation allowed for less straightening and hence better shaping of the canal and reduced preparation time ($p<0.0001$).

Study results were inconclusive regarding cleanliness of canals using either hand or rotary instrumentation. Considering conservation of tooth structure, transportation, perforation, maintenance of anatomy and time, rotary instruments may be more efficient. However, further studies evaluating the clinical success of automated systems are necessary before rotary instrumentation becomes the standard of practice.

**Keywords**: hand files, rotary files, endodontics

## Introduction

Endodontics is defined by the American Association of Endodontics as a branch of dentistry which is concerned with the morphology, physiology and pathology of the human dental pulp and periradicular tissues.[1] When endodontically treating a tooth, the European Society of Endodontology states that root canal success is dependant upon two major factors: cleaning and shaping.[2]

Cleaning pertains to the sufficient removal of debris, bacteria and smear layer from the root canal.[3] Debris is defined as dentin chips and residual vital or necrotic pulp tissue attached to the

root canal wall. The smear layer is a surface film approximately 1 to 2 µm of dentin particles, residual pulp tissue, and bacterial components that remain on the root canal wall after instrumentation.[3] Therefore, proper cleaning is essential in order to provide an adequate seal and to prevent failure.[4] The goal of shaping the canal is to develop a continuously shaped three-dimensional conical form from the apex of the root to the crown.[5] During shaping, it is critical that the canal anatomy be maintained, tooth structure be conserved, and perforations be minimized by maintaining foramen position.[6]

Both procedures of cleaning and shaping the root canal are performed using endodontic files prior to flushing the canals with irrigants. The gold standard for endodontic files has long been the traditional manual stainless steel hand files.[7] These hand files have undergone some development with the introduction of new materials such as Nickel-Titianium (NiTi) instruments, providing flexibility.[7] In addition, the introduction and continuous development of rotary instrumentation has provided new alternatives.

Previous studies have analyzed and compared the efficiency of hand instruments to rotary instruments under many different conditions. This report is a systematic review of the literature, determining the quality of evidence presently available on this topic, focusing primarily on cleaning and shaping potential.

## Methods

A search of the literature from 1950 to 2007 was conducted to provide an evidence-based recommendation. The keywords hand files, rotary files and endodontics were searched using Ovid/Medline, PubMed, and Cochrane library databases. In addition, articles were given to us by experts in endodontics, Dr. K. Roth and Victor Onwudiwe, a representative from Dentsply Tulsa Dental Specialties. This search yielded 174 articles from both databases and experts: 35, 85, 0, 53, and 1, respectively. Both Dr. K Roth from the University of Toronto Faculty of Dentistry and Victor Onwudiwe, the Dentsply representative, were independently interviewed and provided their opinions on the topic.

At the title stage, 33 articles remained that discussed hand endodontic files and rotary files in the same article. The abstracts were read and the studies included were those conducted by experienced dentists, using human extracted teeth (not a synthetic material) and randomized control trials (RCT). Additionally, studies that employed histological examination or radiographs where histology would not be possible, were used to evaluate the shape and cleanliness of root canals (Appendix 3). The inclusion and exclusion criteria yielded 14 articles. Six additional articles were eliminated upon reading the full text. The remaining eight articles were individually critiqued by three authors using the University of Toronto Community Dentistry Checklist to Assess the Efficacy of Therapy or Prevention (Appendix 1). After a consensus was reached, a minimum of 12/19 on the checklist was established in order to accept three articles for the systematic review.

The level of evidence and recommended grades for specific clinical preventive actions were then assigned to each article based on the Canadian Task Force (CTF) on the Periodic Health

Examination (Appendix 2). Since all of the articles were RCT studies, they received a level of evidence of I and varying recommendation grades for each article.

**Results**

A systematic review of the current literature was carried out in an attempt to determine the efficacy of cleaning and shaping canals when comparing hand and rotary instrumentation. RCT studies that satisfied the specific inclusion and exclusion criteria while achieving a score of 12/19 or higher on a checklist to assess efficacy, were chosen.

In the study conducted by Schafer and Zapke (2000), 120 human extracted teeth with both straight (n=60) and curved canals (n=60) were evenly distributed among five test groups for a scanning electron microscope investigation (Table 1). The intervention groups included the rotary instruments, KaVo-Endo Flash (stainless steel) and the ProFile System (Ni-Ti). The control groups examined the K-flexofile manual files (stainless steel) in two groups) two different techniques) and Hedstrom files (stainless steel) in another control group. Although neither method produced completely clean canals on the basis of smear layer and debris analysis, a comparison of manual files and the KaVo-Endo Flash rotary files showed an equivalent degree of cleanliness ($p<0.05$). In contrast, the best outcome in terms of shaping ability was seen with the ProFile System.

Tan and Messer (2002) examined differences in cleaning and shaping in the mesiobuccal canals of 30 mandibular molars (Table 2). They limited their tooth specimens to those with narrow canals with moderate (n = 17) to severe (n = 13) curvature. The teeth were randomly divided into three groups of ten teeth each, ensuring that both types of curvature were equally divided amongst the groups. The two control groups were those instrumented with manual K files (stainless steel) without coronal flaring and those instrumented after coronal flaring. The intervention group was instrumented with nickel titanium (Ni-Ti) rotary instruments. Preflaring of canals was evaluated as earlier studies showed that it shapes the coronal two-thirds of the canal and removes any cervical interference, which might affect the procedure[10]. It was found that relative to hand files, rotary instruments produced significantly cleaner canals with less apical transportation and hence were better able to maintain the initial canal curvature.

Schafer *et al.* (2004) conducted the only clinical study that looked at the effect of rotary nickel titanium (NiTi) Flex-Master files and hand instruments on the extent of straightening of curved root canals in maxillary and mandibular premolars and molars (Table 3). Eight experienced dentists in private practice prepared 110 canals using Flex Master rotary files and prepared 84 canals using hand files. The study showed that the use of the Flex Master rotary instruments resulted in significantly less straightening ($p < 0.0001$) compared with hand instrumentation, as well as a reduced working time ($p < 0.0001$).

**Discussion**

Schafer and Zapke (2000) received a level of evidence of I and the CTF recommendation of Grade B indicates that there is fair evidence to support the use of rotary instrumentation over manual hand files. Although the

cleaning ability of the KaVo-Endo Flash rotary device was equivalent to Hedstrom and K-Flexofiles, shaping of the root canal was improved with the use of the ProFile rotary system over both manual files and KaVo-Endo Flash rotary instruments. Therefore, the cleaning and shaping ability of different rotary instruments cannot provide Grade A recommendations to suggest their overall efficacy in comparison to manual files, as the difference may be inherent in the design and material of the instruments. This in vitro study unfortunately does not mimic a clinical situation since the biological factors that contribute to root canal failures cannot be evaluated. Furthermore, pre-bending of instruments was not conducted in vitro, which is standard clinical procedure during debridement of curved canals to ensure minimal straightening[4].

The study by Tan and Messer (2002) was assigned a level of evidence of I with a recommendation grade B, indicating that there is fair evidence to recommend the use of rotary instrumentation. Although outcomes of cleaning and shaping were better with the automated system, this study had several weaknesses. Light microscopy was used to evaluate the specimens and although this allows determination of removal of dentin debris, removal of the smear layer cannot be assessed without scanning electron microscopy. Also, the results of this in vitro study design may not extend to in vivo situations where other factors may influence clinical success. In regards to the instruments used, Ni-Ti files had an inherent advantage as they are more flexible than stainless steel hand files and thus are better able to accommodate curved canals. To eliminate any influence the instrument material may have on the outcome, both Ni-Ti hand and rotary instruments should have been employed. Lastly, this study had a smaller sample size than the other studies evaluated, which weakens the study design.

Schafer *et al.* (2004) reported a significant difference in the maintenance of canal curvature as well as preparation time when comparing rotary and hand instrumentation. This RCT received a level of evidence score of I and was assigned grade B recommendation, suggesting that there is fair evidence to recommend rotary instrumentation in the preparation of root canals. In this study the hand files served as the control treatment, which is the standard of care, while rotary instrumentation served as the intervention treatment. The results were such that the rotary instrumentation was superior to hand instrumentation in shaping the canals ($p < 0.0001$). The study design, however, had some limitations. The eight dentists did not treat the same number of teeth since three of the eight dentists performed most of the preparations. Also, the material composition of the hand files was not consistent; the majority of the preparations were prepared with stainless steel files, while six preparations were done with Ni-Ti. In addition, the evaluation of the preparation was done using two dimensional radiographs; evaluating three dimensional canals in this way can be inaccurate. Lastly, there was no follow up study to assess the outcomes of each treatment although it may have been possible.

The two most important objectives in root canal preparation, shaping and cleaning, were both analyzed in the aforementioned articles. Studies showed inconclusive evidence

regarding cleanliness capabilities. Schafer and Zapke (2000) was not able to find a significant difference between hand and rotary instrumentation, whereas Tan and Messer (2002) found that there is a significant difference in the cleaning ability of rotary instruments at the most apical regions of the tooth. In regards to shaping of root canals, consistent evidence has been found in all three studies, stating that there is an advantage to the use of rotary instrumentation due to minimized canal straightening, canal transportation, and perforation. Although all studies were randomized controlled trials, the studies tested for technical quality only and do not provide results on the clinical success of these treatments. In order to assign a grade A recommendation, in vivo studies with follow-up examinations on the clinical success are necessary. Therefore, the recommendation grade established for this study is B, indicating that there is fair evidence to recommend the clinical use of rotary over hand instrumentation in root canal preparation.

Technological advances in the field of endodontics have provided promising results, especially with respect to clinically important variables such as conservation of tooth structure, transportation, perforation, maintenance of anatomy and time. Regardless, more in vivo studies are needed to evaluate the clinical success of these tools before rotary instrumentation becomes standard practice.

**References**


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Table 1: Comparative scanning electron microscope investigation of the efficacy of manual and automated instrumentation of root canals

| **Author/ Date** | **Population** | **Intervention, or Test treatment (Number studied)** | **Control Treatment (Number Studied)** | **Outcome** | **Critical appraisal / comments/strength of study/Conclusions** |
|---|---|---|---|---|---|
| Schafer and Zapke, 2000 | -120 human extracted teeth:<br> 60 incisors (straight roots/root canals)<br>- 60 upper and lower molars (at least one curved root/root canal)<br>- No age or sex matching conducted<br><br><u>Inclusion criteria</u>:<br>1.Clinical crowns were largely intact<br>2. Root canals freely accessible with a root canal instrument size 10 up to the intact root tip.<br>3. Root canal width near apex is approximately compatible with size 15 | ROTARY INSTRUMENTS (NiTi)<br>- 48 teeth: 12 straight and 12 curved canals with Kavo-Endo Flash, and 12 straight and 12 curved canals with ProFile system) | MANUAL INSTRUMENTS (stainless steel)<br>- 72 teeth (K-Flexofile, Step-back Technique with K- Flexofile, and Hedstrom files) | Debris and smear layer was examined under scanning electron microscope -- evaluated according to a numerical scale published by Hulsmann *et al*.<br><br>OUTCOME 1 (Cleaning)<br>- Neither method produced completely clean canals<br>- Better cleaning in straight roots & coronal & middle 1/3s<br>- Hand instruments and KaVo Endo Flash produced the best cleaning: significant differences in scores for debris and smear layer ($p < 0.001$) for both curved and straight roots<br>- ProFile instruments produced a thicker smear layer (lower cleaning efficiency)<br><br>OUTCOME 2 (Shaping)<br>Best with ProFile instruments especially in curved roots, worst with Hedstrom files in curved canals | - an in vitro study done on extracted teeth<br>- One investigator and blinded SEM evaluations by another investigator (double blinding not possible here)<br><br>CRITICISM:<br>- Better to have compared hand and rotary instruments made of the same material<br>- More than one investigator may have been more ideal to control for each investigator technical errors and clinical tendencies<br>- Only 12 teeth per group (small sample size)<br><br>• Recommendation grades: B<br>• Level of Evidence: I<br>• Check list score 12/19<br>CONCLUSION:<br>- Comparison of manual instrumentation with K-Flexofiles or Hedstrom files and the rotary KaVo-Endo Flash device resulted in an equivalent degree of canal cleaning. -- Rotary ProFile System resulted in the best shaping of curved canals and worst shaping with hand files |

Table 2: The Quality of Apical Canal Preparation Using Hand and Rotary Instruments with Specific Criteria for Enlargement Based on Initial Apical File Size

| **Author/ Date** | **Population** | **Intervention, or Test treatment (Number studied)** | **Control Treatment (Number Studied)** | **Outcome** | **Critical appraisal / comments/strength of study/Conclusions** |
| --- | --- | --- | --- | --- | --- |
| Tan and Messer 2002 | - Freshly extracted mandibular human teeth<br>- No age or sex matching conducted<br><br><u>Inclusion criteria</u>:<br>1. Mandibular molars with narrow mesiobuccal root canals.<br>2. Root apices fully developed<br>3. Narrow mesiobuccal canals with moderate to severe curvature | ROTARY INSTRUMENTS (NiTi)<br><br>Group : (LightSpeed or LS rotary instrumentation (10 mandibular molars) | MANUAL INSTRUMENTS K Files (stainless steel)<br><br>Group 1:<br>-K files without coronal flaring (10 mandibular molars)<br><br>Group 2: K files with coronal flaring (10 mandibular molars) | - Remnants of pulp tissue and dentin debris was examined under light microscope – evaluated using a grid system and numerical scores<br>-Canal transportation evaluated using method published by Pedicord *et a*l.<br><br>OUTCOME 1 (Cleaning)<br>- All canals cleaner at apical 3mm level relative to apical 1 mm level<br>- At apical 1 mm level, LS yielded significantly cleaner canal walls that were planed.<br>- Hand resulted in more residual debris<br>-At apical 3mm, no major differences in total % of canal wall score 0 or 1<br><br>OUTCOME 2 (Shaping)<br>-Overall, greater canal transportation at 1-mm level vs 3-mm level.<br>- At apical 1mm level, 9 of 10 canals in group 1, 8 of 10 in group 2 and only 2 of 10 in group 3 were transported<br>- Most canal tranportation in mesial direction, indicating straightening of canal | - types of curvature randomly assigned to all 3 groups<br>- blinded evaluation of specimens under light microscope<br><br>CRITICISM:<br>-only 30 teeth used<br>-hand and rotary instruments were different materials<br>-LS canals more round but not always ideal esp for original canals that are slit-like or ovoid to begin with<br>- No smear layer evaluation because did not use SEM<br><br>• Recommendation grades: B<br>• Level of Evidence: I<br><br>CONCLUSION:<br>- LS instrumentation gave greater enlargement of the apex, significantly cleaner canals and less apical transportation<br>- effect of coronal flaring not apparent |

Table 3: Comparison of Hand Stainless Steel and Nikel Titanium Rotary Instrumentation: A Clinical Study

| Author/ Date | Population | Intervention, or Test treatment (Number studied) | Control Treatment (Number Studied) | Outcome | Critical appraisal / comments/strength of study/Conclusions |
|---|---|---|---|---|---|
| Schafer et al.,2004 | -194 root canals of maxillary and mandibular premolars and molars (Human non-extracted teeth- *in vivo)*<br>- No age or sex matching conducted<br><br>Inclusion criteria:<br>1. Tooth must have at least one curved canal<br>2. Preoperative canal angulation 10 degrees or more<br>3. Per tooth only the canal with the greatest preoperative curvature was used<br>4.Canals with more than one curve (s-shaped) were eliminated<br>5.Canals that could not be distinguished from each other on working length/radiograph were eliminated | ROTARY INSTRUMENTS (NiTi)<br>- 110 canals (FlexMaster NiTi, crown-down technique, yellow-coded instrumentation sequence provided by manufacturer) | MANUAL INSTRUMENTS (78 stainless steel, 6 NiTi)<br>- 84 canals ( balanced force technique or reaming and filing working motions) | - Root canal curvature and degree of straightening were assessed by taking pre and post-opt radiographs using a computerized digital image processing system to make the measurements.<br><br>OUTCOME (Straightening)<br>- use of FlexMaster instruments resulted in significantly less straightening ($p<0.0001$)<br>- FlexMaster automated instruments resulted in significantly shorter preparation time ($p<0.0001$) | -a rare in vivo study done on patients, more realistic<br>-performed by experienced dentists<br>- Reproducibility of radiograph measurements assessed (found to be with in +/- 3%)<br>-Blinded evaluation of curvatures before and after instrumentation<br><br>CRITICISM:<br>- inaccuracies likely in using 2D radiograph to assess 3D canal straightening<br>-NiTi hand files were included in the results with the stainless steel hand files<br>- three of the eight dentists treated the majority of the root canals<br>• Recommendation grades: B<br>• Level of Evidence: I<br>• Check list score: 14/19<br><br>CONCLUSION:<br>- Manual instrumentation vs. FlexMaster automated instrumentation resulted significantly less straightening and shorter preparation time. |

**Appendix 1**

## University of Toronto Community Dentistry Checklist to Assess Evidence of Efficacy of Therapy or Prevention

1. Was the study ethical? ___
2. Was a strong design used to assess efficacy? ___
3. Were outcomes (benefits and harms) validly and reliably measured? ___
4. Were interventions validly and reliably measured? ___
5. What were the results?
    - Was the treatment effect large enough to be clinically important? ___
    - Was the estimate of the treatment effect beyond chance and relatively precise? ___
        - If the findings were "no difference" was the power of the study 80% or better __

6. Are the results of the study valid?
    - Was the assignment of patients to treatments randomized? ___
    - Were all patients who entered the trial properly accounted for and attributed at its conclusion? e.g.,

        i) Was loss to follow-up less than 20% and balanced between test and controls or, if not, the effects of those losses satisfactorily accounted for ___

        ii) Were patients analyzed in the groups to which they were randomized? ___
        - Was the study of sufficient duration? ___
        - Were patients, health workers, and study personnel "blind" to treatment? ___
        - Were the groups similar at the start of the trial? ___
        - Aside from the experimental intervention, were the groups treated equally? ___
        - Was care received outside the study identified and controlled for ___

7. Will the results help in caring for your patients?

    Were all clinically important outcomes considered? ___

    Are the likely benefits of treatment worth the potential harms and costs? ___

Adapted from: Fletcher, Fletcher and Wagner. Clinical epidemiology – the essentials. 3rd ed. 1996, and Sackett et al. Evidence-based medicine: how to practice and teach EBM. 1997

**Appendix 2**

**Table 1. Recommendations Grades for Specific Clinical Preventive Actions**

| | |
|---|---|
| **A** | The CTF concludes that there is **good** evidence to recommend the clinical preventive action. |
| **B** | The CTF concludes that there is **fair** evidence to recommend the clinical preventive action. |
| **C** | The CTF concludes that the existing evidence is **conflicting** and does not allow making a recommendation for or against use of the clinical preventive action, however other factors may influence decision-making. |
| **D** | The CTF concludes that there is **fair** evidence to recommend against the clinical preventive action. |
| **E** | The CTF concludes that there is **good** evidence to recommend against the clinical preventive action. |
| **I** | The CTF concludes that there is **insufficient** evidence (in quantity and/or quality) to make a recommendation, however other factors may influence decision-making. |
| *The CTF recognizes that in many cases patient specific factors need to be considered and discussed, such as the value the patient places on the clinical preventive action; its possible positive and negative outcomes; and the context and /or personal circumstances of the patient (medical and other). In certain circumstances where the evidence is complex, conflicting or insufficient, a more detailed discussion may be required.* | |

**Table 2. Levels of Evidence - Research Design Rating**

| | |
|---|---|
| **I** | Evidence from randomized controlled trial(s) |
| **II-1** | Evidence from controlled trial(s) without randomization |
| **II-2** | Evidence from cohort or case-control analytic studies, preferably from more than one centre or research group |
| **II-3** | Evidence from comparisons between times or places with or without the intervention; dramatic results in uncontrolled experiments could be included here |
| **III** | Opinions of respected authorities, based on clinical experience; descriptive studies or reports of expert committees |

**Appendix 3**

| Excluded Articles | Reason for Exclusion |
| --- | --- |
| Peru, M., Peru, C., Mannocci, F., Sherriff, M., Buchanan, L.S., Pitt, Ford. T.R. (2006), “Hand and nickel-titanium root canal instrumentation performed by dental students: a micro-computed tomographic study,” *European Journal of Dental Educations*, **10**(1), 52-9. | • Dental students were used in this study to perform the preparations<br>• Used resin teeth |
| Zmener O., Pameijer C. H., Banegas G. (2006), “Retreatment efficacy of hand versus automated instrumentation in oval shaped root canals: an *ex-vivo* study”, *International Endodontic Journal,* **39**, 521-526 | • Retreatment and removal of gutta-percha<br>• Weak design |
| Mandel E., Machtou p., Friedmann S (1990), “Scanning electron microscope observation of canal cleanliness” *Journal of Endodontics*, **16**(6), 179-83. | • Results are not statistically significant<br>• Unreliable outcomes |
| Schirrmeister J. F, Strohl C., Altenburger M.J., Wrbas K. T, Hellwig E., (2006), “Shaping ability and safety of five different rotary nickel-titanium instruments compared with stainless steel hand instrumentation in simulated curved root canals,” *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* **101**(6), 807-13. | • Resin simulated root canal blocks were used instead of real teeth<br>• Preparations were evaluated using a dye-marker instead of SEM |