Evaluation of Complications of Root Canal Treatment Performed by Residents and Endodontic Specialists Using Contemporary Techniques: A Retrospective Study

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Abstract

Objectives: Endodontic treatment has benefited from the development of new techniques and equipment. Few clinical studies have been published on the complications associated with root canal preparations performed by doctors with different working experiences using contemporary techniques. This study aimed to analyze the complications of endodontic treatment performed by residents and endodontic specialists in a teaching stomatology hospital using contemporary techniques.

Materials and Methods: Cases of root canal treatment (RCT) and root canal retreatment (ReRCT) performed by residents and endodontic specialists were collected from the electronic medical system of the Beijing Stomatology Hospital. The cases were examined in terms of patient age, sex, type of tooth, diagnosis, treatment plan, number of appointments, whether a rubber dam and operating microscope were used, type of irrigation used, presence of ledges, canal transportation, perforations, missed canals, separated instruments, clinical incidence of second mesiobuccal (MB2) root canal in the maxillary molars, and occurrence of flare-ups.

Results: In total, 859 patients were included in the analysis. The overall incidence of complications in the resident group were significantly higher than in the specialist group. More ledges and flare-ups were observed in the resident group. There were no significant differences in root canal transportation, perforation, or instrument separation between the two groups. The findings of MB2 in the maxillary molars were significantly higher in the specialist group. Univariate analysis showed that the incidence of root canal preparation complications was related to operator experience and tooth type.

Conclusion: Operator experience influenced ledges, flare-ups, and finding MB2, but did not affect root canal transportation, perforation, or instrument separation with contemporary techniques.

Clinical Relevance: With the development of new techniques and equipment of endodontics therapy, whether clinical experience has an effect on the complications of root canal treatment.

Introduction

The preparation of root canals is one of the most important procedures in endodontic treatment, shaping root canals, and preparing them for root canal filling. Complications may occur during root canal preparation due to the complexity and irregularity of the root canal system. Root canal complications, or “catastrophic errors,” which include ledges, canal transportation, perforations, separated instruments, missed canals, and flare ups, might ultimately lead to treatment failure [1-6].

Previous studies have reported that ledges, apical transportation, and foramen perforations are commonly observed during root canal instrumentation in undergraduate students using stainless-steel K-files [7,8]. However, better canal preparations were achieved using rotary nickel-titanium (NiTi) instruments than with manual files [9,10]. Research indicates that 51.5% of the canals treated by students have been ledged, and the percentage treated by endodontists is 33.2% in teeth with intact pulp cavities;

however, ledges occur in 40.6% of cases of endodontic retreatment [2]. A study of 2000 cases performed by a specialist indicated that the incidence of complications is only 2.5% [1]. Experience has been found to improve the ability of endodontic residents to locate and fill additional canals in maxillary molars and has an influence on the prevalence of postoperative pain after root canal treatment (RCT) [11,12]. Most of these studies were published between 2000 and 2010 and used stainless-steel K-files or traditional rotary NiTi instruments [1,2,7-10]. Generally, the occurrence of iatrogenic errors may be affected by operator experience. However, two *in vitro* studies published in 2014 and 2016 indicated that operator experience does not influence shaping ability in a single-file reciprocating motion system [13,14].

In recent years, endodontic treatment has benefited from the development of new techniques and equipment. The use of operating microscopes and ultrasonic instruments has improved the efficiency and outcomes of endodontic treatment [15,16]. New processing technology and thermal treatment have improved the physical and mechanical properties of NiTi instruments, resulting in better torsional resistance, fatigue lifetime, and flexibility [17-19]. To our knowledge, few clinical studies on the complications of RCTs performed by doctors with different working experiences using contemporary techniques have been published to date. Whether technical advancement could reduce the effect of working experience on RCT complications and whether there is a greater risk of serious complications in a teaching stomatology hospital requires further study. The aim of this study was to analyze the complications of RCT performed by residents and endodontic specialists at the Beijing Stomatology Hospital using contemporary techniques.

Materials and Methods

Case selection

Cases of RCT and non-surgical RCT (ReRCT) performed by residents with 1–3 years of working experience (Group R) and endodontic specialists with 5–7 years of working experience (Group S) were collected from the electronic medical system of the Department of Endodontics, Beijing Stomatology Hospital, Capital Medical University, Beijing, China, from September 1, 2020 to August 31, 2021. Cases lacking complete dental records or preoperative or postoperative radiographs, cases involving the third molar, and those in which the apical foramen was not fully completed and needed an apical barrier were excluded from the study.

Endodontic therapy procedure

For each case, the following information was recorded from the electronic medical system: patient age, sex, date of treatment, type of tooth, diagnosis, treatment plan (RCT or ReRCT), number of appointments, whether a rubber dam and operating microscope were used, type of irrigation used, clinical incidence of MB_2 root canal in the maxillary first and second molars, and occurrence of flare-ups.

The procedure for RCT is briefly described as follows. Conventional straight-line access preparation was performed after rubber-dam application to ensure isolation. An operating microscope was used to locate

the root canal, and ultrasonic instruments were used to gain access to the canal openings. Root canal preparations were performed using the crown-down instrumentation technique with M3-Pro (United Dental, Shanghai, China) rotary NiTi files manufactured using a controlled memory (CM) wire. The preparation was performed according to the manufacturer's instructions. The preparation sequence was a 17/08 M3-Pro file to enlarge the coronal two-thirds of the canal, followed by a small C-file and 19/02, 20/04, 25/04, and 20/06 M3-Pro files to full working length; a 35/04 file may be used if necessary. Working length was determined using an electronic apical locator (Raypex 6; VDW, Munich, Germany) and confirmed using digital radiographs, if necessary. For ReRCTs, previous obturation materials and root canal obstructions were removed using hand files, NiTi files, and ultrasonic instruments under the magnification and lighting of the operating microscope. Root canals were irrigated with 2% chloramine and 1% or 2.5% sodium hypochlorite (NaClO). Therapy was completed during single or multiple treatment visits. In the latter case, calcium hydroxide paste was placed in the canal between appointments. Root canal obturation was performed using the warm vertical compaction technique. Cone-beam computed tomography (CBCT) was performed during the treatment procedure, if necessary.

Evaluation of complications of RCT

Two endodontists with > 7 years of experience evaluated the preoperative, intraoperative, and postoperative radiographs, as well as any progress notes that mentioned one of the procedural errors. In case of controversy, a highly experienced endodontist was consulted to evaluate the radiographs and a final decision was made.

The examiners used the following criteria to evaluate RCT complications by reading radiographs [2, 7, 20, 21]. Ledges were identified when the root canal filling deviated from the original canal shape or when the root filling was more than 2 mm short of the radiographic apex. Root canal transportation was identified when the root canal filling deviated inside or outside the curvature of the root canal, or when the root apex was overcut so that the original position was to be changed. Root perforation was identified as a communication between the root canal space and external root surface. Instrument separation was identified when a radiopaque fractured instrument segment was detected in the root canal or when it extended into the periapical area. Missed canals were identified when the obturation material was positioned asymmetrically along the long axis of the root.

Statistical analysis

Statistical analyses were performed using SPSS for Windows, version 26.0 (IBM, Armonk, NY). Demographic data are presented as frequencies and proportions for categorical variables and as medians and interquartile ranges for continuous variables. Categorical variables were compared using the chi-squared test or Fisher's exact test for equal proportions. Dichotomous variables are presented as percentages and compared using Fisher's exact test. Univariate and multivariate analyses were used to evaluate joint associations among various factors using logistic regression models. All statistical tests were two-tailed and were interpreted at a 5% significance level.

Results

A total of 881 patients were included in this analysis. After excluding 2 cases of the third molar and 20 cases that required an apical barrier, a total of 859 cases were included (401 cases in Group S and 458 cases in Group R).

Basic information of patients and teeth

The basic information of the two groups was shown in Table 1. There were no significant differences in sex between the two groups. The patients in Group S were significantly older than those in Group R. Specialists treated significantly more molars, more teeth that needed ReRCT, and more teeth with apical periodontitis than residents. There were significantly fewer appointments in Group S than in Group R.

In the process of root canal preparation, the rates of using a rubber dam, operating microscope, and NaClO irrigation were significantly higher in Group S than in Group R. Similarly, in the process of root canal obturation, the rates of using a rubber dam, operating microscope, and NaClO were also significantly higher in Group S.

Table 1. The basic information of two groups

	Specialists (n=401)	Residents (n=458)	*p*
Age	37 28, 50	33 27, 42	0.001
Sex (female)	242 60.3%	297 65.0%	0.161
Tooth with apical periodontitis	146 36.4%	106 23.1%	0.001
Type of tooth			
Anterior tooth and premolar	165 41.1%	242 52.8%	0.001
Molar	236 58.9%	216 47.2%	0.001
Root canal retreatment	95 23.7%	49 10.7%	0.001
Number of appointments	2.3±0.6	2.9±0.9	P=0.002
Using rubber dam during root canal preparation	356 88.8%	263 57.4%	0.001
Using operating microscope during root canal preparation	396 98.8%	207 45.2%	0.001
Using NaClO during root canal preparation	316 78.8%	121 26.5%	0.001
Using rubber dam during root canal obturation	391 97.5%	316 69.0%	0.001
Using operating microscope during root canal obturation	397 99.0%	239 52.2%	0.001
Using NaClO during root canal obturation	364 90.8%	142 31.0%	0.001

Complications of RCT

The overall incidence of complications was significantly higher in Group R than in Group S. More ledges and flare-ups were observed in Group R. There were no significant differences in root canal transportation, root perforation, or instrument separation between the two groups (Table 2).

Table 2. Frequency of complications of two groups

	Specialists	Residents	*p*
	n=401	**n=458**	
Total complications	32 8.0%	72 15.7%	0.001
Ledge	16 4.0%	37 8.1%	0.013
Flare up	8 2.0%	22 4.8%	0.025
Root canal transportation	1 0.2%	5 1.1%	0.139
Root perforation	1 0.2%	4 0.9%	0.230
Missed canal	2 0.5%	5 1.1%	0.335
Instrument separation	4 1.0%	6 1.3%	0.670

Findings of MB2

There were 58 and 36 maxillary first and second molars in Group R and 62 and 51 in Group S, respectively. The clinical incidence of MB2 canals in the maxillary first and second molars was significantly higher in Group S (Figure 1).

Univariate and multivariate analysis of complications

Univariate analysis revealed that the incidence of complications was related to operator experience and tooth type. After adjusting for multivariate analysis, complications were found to be associated with operator experience, tooth type, and treatment protocol (Table 3).

Table 3. Univariate and multivariate analysis of complications

	Univariate analysis		**Multivariate analysis**	
	OR [95% CI]	*p*	OR [95% CI]	*p*
Residents	2.151[1.385-3.340]	0.001	3.373[2.033-5.598]	0.001
Molar	2.010[1.303-3.102]	0.002	1.784[1.102-2.888]	0.019
Root canal retreatment	1.488[0.900-2.458]	0.121	1.856[1.085-3.176]	0.024
Age	0.986[0.971-1.002]	0.091	0.991[0.974-1.007]	0.278
Using operating microscope during root canal preparation	0.805[0.506-1.282]	0.362	0.658[0.368-1.175]	0.157
Using rubber dam during root canal preparation	0.619[0.374-1.025]	0.062	0.663[0.362-1.214]	0.183

Discussion

In this retrospective study, initial endodontic treatment and non-surgical endodontic retreatment were performed by residents with 1–3 years of working experience and endodontic specialists with 5–7 years of working experience in the Department of Endodontics, Beijing Stomatology Hospital, Capital Medical University. As a stomatology hospital, a certain number of cases were referred from general hospitals, community hospitals, or private clinics that had calcified or curved root canals or failed initial endodontic treatment that required non-surgical retreatment. Beijing Stomatology Hospital is also a teaching hospital that undertakes many teaching tasks and trains medical students at different stages, including undergraduates, postgraduates, and residents. Therefore, it is worth investigating whether there is a higher risk of serious complications. Previous clinical studies have reported that students develop more complications. However, these clinical studies were conducted before many modern endodontic techniques became available, using Gates–Glidden burs and stainless-steel hand files for root canal preparation between 2000 and 2010 [1, 2, 7, 8]. In our study, endodontic treatment was performed using modern techniques, such as ultrasonic instruments, new rotary NiTi file systems, operating microscopes, and CBCT scanning, if necessary. As residents have a few years of clinical experience, they can perform certain complicated endodontic treatment procedures independently; so, we chose residents and young specialists as research subjects. Therefore, the present study was performed to determine whether there is a greater risk of serious root canal complications when performed by residents and young endodontic specialists using modern endodontic techniques in a teaching stomatology hospital.

The root canals of molar teeth are more curved and narrower than those of the premolar and anterior teeth. Older adults are more likely to have calcified canals due to aging-related changes, which presents a practical challenge to clinicians during RCT [22]. In addition, the healing rate of teeth with lesions was significantly lower than that of teeth without lesions, requiring stricter treatment standards [1]. What' more, several challenges are faced during retreatment, including the removal of the previous obturation material, correction of procedural errors generated during the previous treatment, such as ledges, root canal transportation, or perforation, locating missed canals, and eliminating infected pulp and therapy-resistant bacteria. Our results were in line with previous suppositions that specialists preferred to treat more difficult cases than residents, which consisted of more molars (58.9% vs. 47.2%, $p = 0.001$), more teeth with periapical lesions (36.4% vs. 23.1%, $p < 0.001$), and more ReRCTs (23.7% vs. 10.7%, $p < 0.001$).

Although specialists treat more difficult cases, they actually needed fewer appointments to complete treatment than residents (2.3 ± 0.6 vs. 2.9 ± 0.9, $p = 0.002$). These results are similar to those of previous studies [23, 24]. This may be because specialists are more knowledgeable, professional, and skillful; therefore, they are more efficient in their treatment.

In the present study, the specialists were more accustomed to using an operating microscope and rubber dam as conventional procedures during treatment. During isolation with rubber dams, specialists used NaClO instead of chloramine for irrigation. On the one hand, cases performed by residents were not as complicated as those performed by specialists; on the other hand, residents may sometimes be unaware

of the difficulty of certain cases, such as looking for the MB2 root canal of the maxillary molar. As such, they may not have thought it was necessary to use an operating microscope or rubber dam in some cases. However, the use of an operating microscope and rubber dam could increase treatment costs for patients, leading to lower patient satisfaction in a previous study [23].

Our results are in line with those of a previous study in which more ledges were observed in the resident group [2, 7, 8]. The residents were not as skilled or knowledgeable as the specialists and were not familiar with the anatomical morphology of the root canal. They may not be aware of pre-curved hand files when negotiating curved canals. In addition, the ledge rate of the resident group was 8.1% in our study, which was lower than those reported in previous studies [2, 7, 8]. This may be because a contemporary treatment procedure was followed, which represents the current standards of endodontic therapy in our study, including the use of operating microscopes, CM-wire rotary instruments, and ultrasonic instruments.

In addition, more flare-ups were observed in the resident group. Flare-ups are a multivariate problem in clinical practice, but one of the principal causes is inflammation caused by the extrusion of contaminated debris into the periradicular tissues [25]. This may be attributable to the dexterity and skill of the operators. Residents have a poorer ability to control the working length during treatment than specialists; therefore, instruments may extend beyond the apical foramen. Once flare-ups appeared, residents needed more inter-appointment medications to lessen symptoms, which led to more treatment appointments. However, the main concern of postoperative pain studies is the subjective evaluation of pain levels. In our study, severe percussion pain and swollen gums were used to identify flare-ups, which could reduce the interference of subjective consciousness.

We examined several factors, including age, tooth type, treatment protocol, use of a rubber dam and operating microscope during root canal preparation, and operator experience, to assess significant outcome predictors. The results indicated that the type of tooth and operator experience significantly affected the outcome according to the univariate and multivariate logistic regression models, and the treatment protocol significantly affected the outcome according to the multivariate logistic regression models. Our results are in line with those of previous studies that reported that the occurrence of complications was affected by the type of tooth and the root canal curvature [2, 20]. When dealing with ReRCT, correcting procedural errors, such as ledges, root canal transportation, and perforation, has been a major challenge.

Although these complications were slightly more frequent in the resident group, root canal transportation, perforation, and instrument separation occurred infrequently with no significant differences between the two groups. This might be attributable to the improved torsional resistance, fatigue lifetime, and flexibility of the CM-wire NiTi instruments, as several studies have highlighted their benefits [17–19, 26]. Analysis of another clinical study might be necessary to better understand the effect of traditional NiTi instruments and CM-wire NiTi instruments on the frequency of root canal transportation, perforation, and instrument separation.

In the present study, the clinical incidence of MB2 canals in the maxillary first and second molars reported by residents was 25.9% and 16.7%, respectively, which was significantly lower than that reported by specialists (69.4% and 21.6%, respectively). Our results by specialists were in line with previous studies that showed that the incidence of MB2 canals was 62–69% in the laboratory phase [27, 28], and 71% and 77% by experienced endodontists [29, 30]. However, the incidence of MB2 canals among the residents was relatively low. Research has confirmed that operating microscopes and operator experience affect the location of additional canals in the MB root of maxillary molars [11, 15]. In our study, the rate of operating microscope use during root canal preparation by residents was only 45.2%, which was significantly lower than that of specialists (98.8%). Therefore, whether residents were aware of looking for extra canals using operating microscopes and ultrasonic instruments was most likely to account for the findings of MB2 canals. Another advancement in endodontics used in our study was CBCT imaging, which helped locate extra canals. However, owing to defects in the electronic medical system, the overall number of CBCT scans performed could not be counted.

In conclusion, despite the limitations of this retrospective study, the results indicated that specialists prefer to treat more difficult cases than residents. Operator experience influenced ledges, flare-ups, and MB_2 findings, but did not affect root canal transportation, perforation, or instrument separation with contemporary techniques. Technical advancement could reduce the effect of working experience on RCT complications in some ways. A special training protocol may be useful in designing future clinical trials to draw definitive conclusions on the effects of reducing the complications of RCT.

Declarations

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Author contribution All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Tongfei Shao and Rui Guan. The first draft of the manuscript was written by Tongfei Shao and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability The data that support the findings of this study are not publicly available due to confidentiality reasons. The anonymized statistical data is available from the corresponding author (Benxiang Hou) upon reasonable request.

Ethics approval This retrospective study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Approval was obtained from the Research

Ethics Committee of Beijing Stomatology Hospital, Capital Medical University (reference no. CMUSH-IRB-KJ-PJ-2022-18).

Consent to participate Verbal informed consent was obtained by telephone prior to the study.

Consent to publish Patients signed informed consent regarding publishing their data.

Conflict of Interest The authors declare that they have no conflict of interest.

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Figures

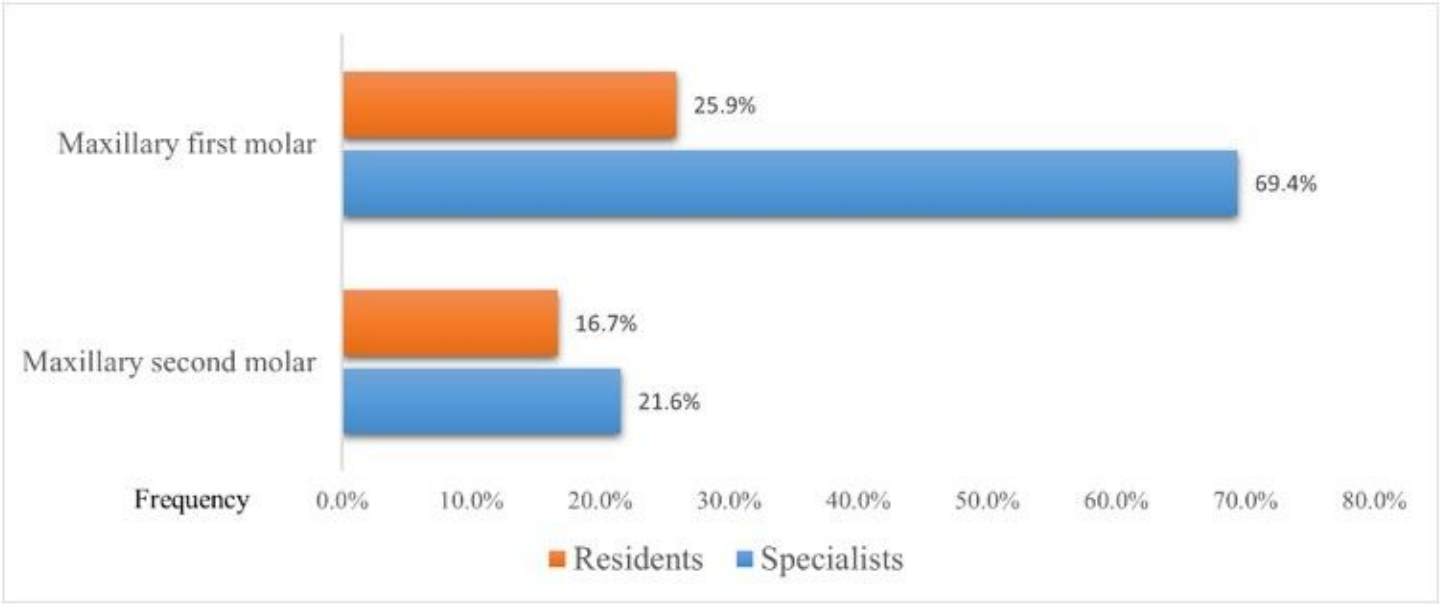

Figure 1

The clinical incidence of MB2 in maxillary first and second molar of two groups