

Effects of different root canal preparation methods on root fracture resistance: A systematic review of the literature

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and 11 kinds of Chinese or English dentistry journals. Retrieval time on Internet was in all years and hand retrieval time was from January 2013 to October 2013. The literatures were selected through reading abstracts and full texts by two reviewers independently and Revman 5 software was used to analyze the literature.

RESULTS: Six articles met the inclusion criteria. According to Meta-analysis of tooth root bending properties, total standardized mean difference (SMD) was 0.63 (95%CI: -0.24-1.50, $P > 0.05$). That indicated there was no statistically significant between the two groups. Subgroup analysis was carried out. SMD were 2.22 (95%CI: 0.23-4.20, $P < 0.05$) and -0.61 (95%CI: -1.05- -0.17, $P < 0.05$) when the premolar teeth with a single canal or the mesiobuccal roots of molars were used as the materials for tests to compare the effects of different root canal preparation methods on root fracture resistance. That only indicated that there were statistically significant in two subgroups.

CONCLUSION: *In vitro* experiments, the effects on the fracture resistance of root had no statistical difference with Ni-Ti rotary instruments and stainless steel hand instruments in root canal preparation.

Key words: Root canal therapy; Root canal preparation; Root fracture; Meta-analysis

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Abstract

AIM: To study the root fracture resistance after root canal preparation with Ni-Ti rotary instruments and stainless hand instruments by means of meta-analysis.

METHODS: Literature was researched in CNKI and CBMDisc, PubMed, CALIS, Proquest, Web of Science

Core tip: There were different opinions on the effect of root fracture resistance using nickel-titanium rotary instrument. The present study carried out Meta-analysis on the references related to the influences on root fracture resistance of two different root canal preparation methods. The result can provide evidence for clinical therapy. The present study confirms that the effects of root canal preparation by Ni-Ti rotary instruments or manual stainless steel instruments on root fracture

resistance are not statistically significant. These two preparation methods are both safe and effective if dentin is not excessively cut under normal chewing conditions.

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INTRODUCTION

So far, root canal therapy is the most thorough and perfect method for endodontic and periapical disease, and root canal preparation is the key procedure for root canal therapy. However, more and more studies showed that the teeth after root canal therapy may have an inclination towards longitudinal fissure in tooth root^[1,2]. Sclerotic tissues of teeth lost nutrients due to removing endodontium in root canal preparation, and dentin became dehydrated and embrittled^[3]. The studies demonstrated that there was a close relationship between tooth resistance and root canal cavity size, lumen wall thickness and cavity shape. Wilcow *et al*^[4] studied 34 maxillary anterior teeth *in vitro* and indicated that subclinical crack was detected in almost 30% of the tooth roots under the same burden on root canal wall when the root canals were enlarged to 20%-30% of the diameters of the root canals. When the root canals were enlarged to 40% of the diameters of the root canals, longitudinal fissure in tooth roots were detected. Sathorn *et al*^[5] prepared root canals and enlarged the middle diameter of root canals progressively in ten mandibular incisors *in vitro*. The results of finite element analysis showed that the root fracture resistance successively decreased for the root canals with diameters at 0.5, 1.0, 1.5 and 2.0 mm^[5]. There was a close correlation between the degree of root canal preparation and tooth resistance. The larger cavity size lead to the less tooth resistance. Thus, the remaining dentine thickness was an important factor affecting root fracture resistance of teeth.

Nickel-titanium rotary instruments have an excellent shaping ability due to ideal remotion ability and flexibility, which ensures a perfect root canal preparation combined with crown-down technique^[6]. Therefore, nickel-titanium rotary instruments have become the main instrument for root canal preparation. However, there were different opinions on the effect of root fracture resistance using nickel-titanium rotary instruments. The present study carried out meta-analysis on the references related to the influence on root fracture resistance of two different root canal preparation methods. The result can provide evidence for clinical therapy.

Table 1 PubMed search strategy

No.	Search history	Limits	Results
I	(Root canal therapy or root canal preparation) and root fracture	Human Chinese or English All years	1014
II	(Nickel-titanium rotary instrument or manual stainless steel instrument) and root fracture	Human Chinese or English All years	27
III	(Hand instruments or rotary instruments) and root fracture	Human Chinese or English All years	32
Total			1073

MATERIALS AND METHODS

Literature retrieval

Using three groups of research terms: "(root canal therapy or root canal preparation) and root fracture", "(nickel-titanium rotary instrument or manual stainless steel instrument) and root fracture", "(hand instruments or rotary instruments) and root fracture". The published literature were assessed in CNKI, CBMdisc, China Academic Library and Information System (CALIS), PubMed (Table 1), Proquest, Web of Science and in 11 Chinese or English dentistry journals by hand. Retrieval time on Internet was in all years and hand retrieval time was from January 2013 to October 2013. The literature was selected through reading abstracts and full texts.

Literature inclusion and exclusion

Literature inclusion criteria: Literature inclusion criteria were made according to Meta rules and then the literature were selected for second time. Literature inclusion criteria were: (1) All experiments were randomized controlled trials and the tested teeth were randomly divided into hand instruments preparation group and nickel-titanium rotary instrument preparation group; (2) The teeth *in vitro* were selected as materials. There were no significant defect and abnormal shape. In every included experiments, the differences in lengths of teeth, buccolingual diameters, mesiodistal dimensions and root tip curvatures should not be statistically significant; (3) Root canal preparation method was the only variable in every experiment; (4) Teeth were similarly handled before testing. Step-back technique was used to prepare root canal in hand instruments group, and crown-down technique was used in nickel-titanium rotary instrument group; (5) The universal loading machine of general international standards was used for the instrument for tests, and 1 mm/min was used as the loading rate; (6) The pressure values when root fracture appeared were recorded; and (7) All data were analyzed by statistic software.

Research data

There were six publications meeting the inclusion

Table 2 The information statistics of included literature

Ref.	Dental notation	Hand preparation numbers	Hand preparation mean	Hand preparation SD	Ni-Ti preparation numbers	Ni-Ti preparation mean	Ni-Ti preparation SD	Ni-Ti instruments taper
Lan <i>et al</i> ^[7] I	Molar	13	10.2	4.4	13	15.7	9.1	0.06
Lan <i>et al</i> ^[7] II	Molar	13	10.2	4.4	13	13.2	6.1	0.08
Ren <i>et al</i> ^[8]	Pre-molar	10	308	8.69	10	228	10.19	0.06
Sathorn <i>et al</i> ^[9]	Incisor	25	113.5	20.2	25	114.9	37.1	0.04
Shi ^[10] I	Pre-molar	8	459.5	163.4	8	436.75	146.58	0.02
Shi ^[10] II	Pre-molar	8	459.5	163.4	8	474.25	101.44	0.04
Shi ^[10] III	Pre-molar	8	459.5	163.4	8	431.38	90.67	0.06
Singla <i>et al</i> ^[11]	Pre-molar	10	482.78	19.33	10	399.07	13.279	0.12
Zare Jahromi <i>et al</i> ^[12]	Molar	16	50.33	19.1	16	63.1	25.46	0.06

criteria^[7-12]. In Lam *et al*^[7] study, there were two experimental groups in different Ni-Ti rotary instruments taper. So there were two randomized controlled trials among two experimental groups and a control group. They were marked as Lam I and Lam II in Table 2. In Shi^[10] study, three experimental groups B1, B2 and B3 and a control group A took root canal preparation method as the only variable. So there were three randomized controlled trials among them. They were marked as Shi I, Shi II and Shi III in Table 2. There were four groups in Singla *et al*^[11] study, but only one randomized controlled trials between hand instruments group and Protaper rotary instruments group fit inclusion criterias^[11].

Essential characteristics of all groups were showed in Table 2.

Meta analysis of inclusive literature

Revman 5 software was used for meta-analysis. Since the measuring units for the included references were not consistent, so standardized mean difference (SMD) analysis was carried out and represented by 95%CI. χ^2 test was carried out to test the heterogeneity among the references. Randomized effect model and fixed effect model were performed respectively in meta analysis when there was statistic significance heterogeneity or not ($P < 0.05$, $I^2 > 50\%$ or $P > 0.05$, $I^2 < 50\%$). Then the forest map was plotted.

Statistical analysis

This document certifies that the statistics in the above manuscript was reviewed and edited by the subject experts (Professional statistician and PhD-level American expert) at 4UPUB to ensure the statistics method, spelling, grammar, and word flow adhere to the standards of professional and academic journals.

RESULTS

Meta analysis of the included literature

In six included literature, nine groups of clinical trials,

there was statistical heterogeneity ($P < 0.05$, $I^2 > 50\%$), so the random effect model of meta analysis was used. The results were showed in Figure 1.

SMD in Figure 1 was 0.63. This indicated that the teeth prepared by manual stainless steel instruments had more root fracture resistance. But the effect quantity was no statistically significant (95%CI: -0.24-1.50, $P > 0.05$).

Subgroup analysis was carried out according to the difference of the tooth positions in each experiment: (1) The premolar teeth with a single canal were used to compare the effects of different root canal preparation methods on root fracture resistance, and the results were shown in Figure 2. The figure indicated that this subgroup of references had statistical heterogeneity ($P < 0.05$, $I^2 > 50\%$). Thus the SMD analysis under the random effect model was used. SMD was 2.22 (95%CI: 0.23-4.20, $P < 0.05$), indicating that the preparation by using Ni-Ti rotary instruments was liable to cause root canal fracture; and (2) The mesiobuccal roots of molars were used to compare the effects of different root canal preparation methods on root fracture resistance, and the results were shown in Figure 3.

The figure mentioned above indicated that this subgroup of references had no statistical heterogeneity ($P > 0.05$, $I^2 = 0$). Thus the SMD analysis under the fixed effect model was used. SMD was -0.61 (95%CI: -1.05- -0.17, $P < 0.05$), indicating that the preparation by using manual stainless steel instruments was liable to cause root canal fracture.

Heterogeneity analysis

As shown in Figure 1, there was statistical heterogeneity among seven included references ($P < 0.05$, $I^2 > 50\%$). By reading literature, significant heterogeneity was found in the references of Ren *et al*^[8] and Singla *et al*^[11], and heterogeneity analysis should be carried out.

The pressure loading direction utilized in the reference of Ren *et al*^[8] had an angle of 15 degrees to the long axis of teeth, namely it simulated the situation for root fracture under lateral pressure load, while the

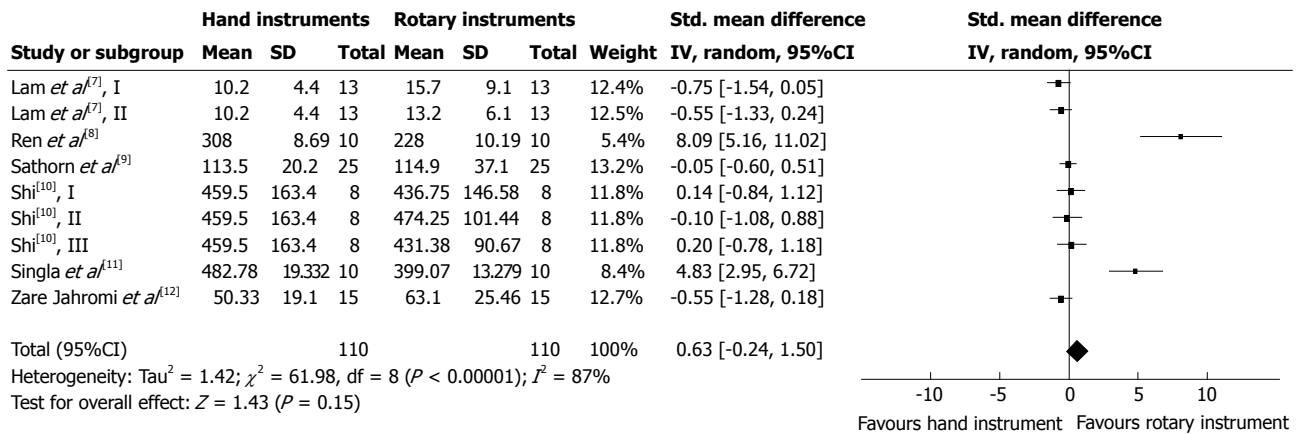


Figure 1 Forest plot of comparison of effects of root fracture resistance.

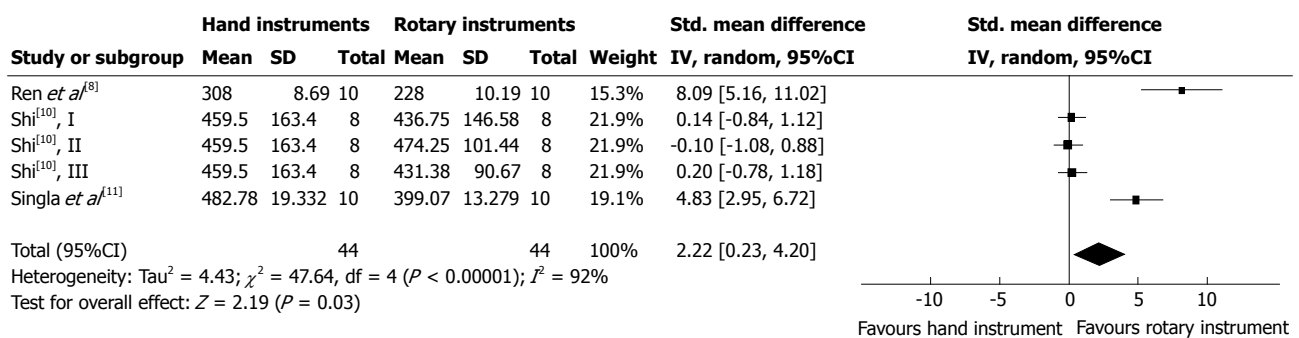


Figure 2 Forest plot of subgroup (premolar).

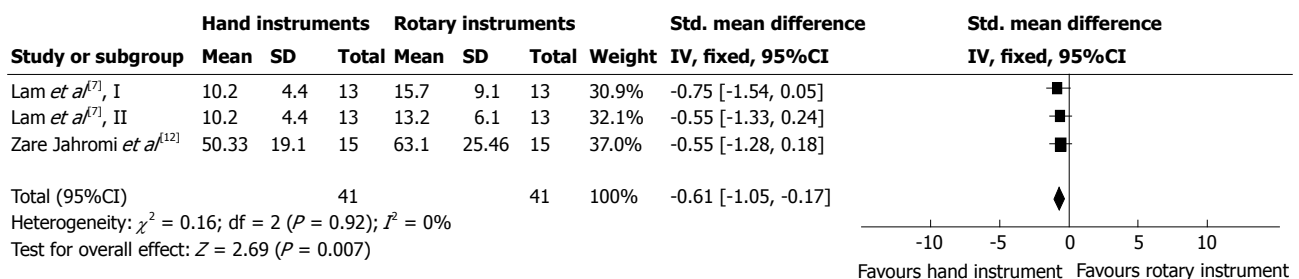


Figure 3 Forest plot of subgroup (molar).

pressure loading directions utilized in other references were paralleled to the long axis of teeth, namely they simulated the situation for root fracture under vertical pressure load. The research showed that the maximal VON MISES stress, the maximal tensile stress and the maximal compressive stress of tooth at lateral loading should be significantly higher than those at vertical loading under the same loading conditions, and they should be located at the middle parts of roots^[13]. The studies also confirmed that the diameter of the middle part in the root canal after preparation with Ni-Ti rotary instruments was significantly bigger than that in the root canal after preparation with manual stainless steel instruments^[14,15]. And the strength of root canals was closely related to the thickness of root canals, so the above factors may contribute to the heterogeneity.

The teeth roots were used in the loading tests after preparation but not filling up in the reference of Singla^[11]. Studies have shown that the fracture resistance of root canal only after preparation was significantly lower than that after perfect root canal treatment^[16,17]. Some scholars also found that filling sealer could significantly enhance the strength of the prepared root canal^[18,19]. So the literature had large heterogeneity.

DISCUSSION

Root canal preparation is an important procedure for root canal therapy, and excellent root canal preparation is the prerequisite for successful root canal therapy. With the development of dentistry, various kinds of Ni-Ti

rotary instruments appear, which have good flexibilities and toughnesses. Using them can decrease root canal perforation and displacement apparently and shorten handling time. Increase in the taper of the instruments can effectively clean and prepare root canals, but it may damage more dentin and thus decrease the strength of tooth root. Many studies demonstrated that there was a positive relationship between the quantity of dentin and intensity of tooth root. There was a lower resistance in teeth after root canal preparation than in teeth without root canal preparation according to all inclusive literature. The statistic difference was significant ($P < 0.05$), which confirmed that root canal preparation decreases intensity of tooth root as well.

Dentin cutting was required for root canal preparation, while the remaining dentin thickness was the most important factor influencing the strength of teeth roots^[20]. At 0.5 mm away from apical stop, same amount of dentin was cut by using manual stainless steel instruments and Greater Taper (GT) rotary instruments, while only 0.25 mm more dentin was cut by using Lightspeed (LS) rotary instruments. But at 4.5 mm away from apical stop, a little more dentin was cut by using GT rotary instruments than using other two kinds of instruments^[7]. Certainly, more dentin is cut by using Ni-Ti rotary instruments than by using manual instruments, but the cross sections are arc-shaped triangles, which decreases the contacting area between rotary instruments and dentin in root canal walls. In addition, since the root canal compactibility was satisfactory, so the root canal taper after preparation was continuous and uniform and the stress could be effectively scattered, which could not only improve the cutting efficiency, but also decrease the stress on root surface during root canal preparation^[21]. So this method can offset the deficiency that cuts more dentin in a certain degree. At the same time, the experiment *in vitro* have established that masticatory force could disperse quickly along the long axis of teeth *via* dental crown under vertical pressure load. Even root canal preparation and filling in large taper were also relatively safe^[22].

The clinical trials confirmed that the stress concentration area in the tooth root was almost consistent with the direction of root fracture. And the stress concentration was closely related to root fracture^[23]. Manual stainless steel instruments cut less dentine, but repeated lifting and dragging was required for preparing ideal root canal morphology, which lead to over-straightening of root canal. The weak parts were liable to fracture because of uneven forces on different parts of root canal wall. Moreover, relatively big stress would be produced on root canal wall and decreased the strength of tooth root during repeated lifting, dragging, enlarging and scraping^[24]. From the point of view of mechanics, structure defects, crack or improper root canal preparation, which would produce multiplied stress, were likely to be the key factors influencing the root canal strength^[25]. Other studies considered

that the rigider root canal file caused stronger stress concentration, which increased the risk of dentin defect and lead to root fracture^[26].

Meanwhile, with the development of digital modeling technique, some scholars analysed the stress of root canal preparation by tooth three-dimension finite element model. The studies showed that the tendency of whole stress distribution on prepared teeth was similar, and the stress at the root canal orifice in the stainless steel instrument group was the highest, but the differences in the stress on root canal wall between root tips and middle parts of root canals were not statistically significant^[27]. Furthermore, the ultimate compressive strength of dentine is 232-305 MPa and the tensile strength is 48-105.5 MPa. Therefore, different root canal preparation methods are safe and reliable without other effective factor. In general, the preparation methods by using Ni-Ti instruments and manual stainless steel instruments may decrease the strength of tooth roots, but the mechanisms are different and the effects on root fracture resistance have not been well defined.

Previous studies have shown that premolar and mesiodistal root canals of mandibular first molar after preparation were liable to fracture, thus most of the researches utilized them as the teeth for tests^[28]. However, premolar and the root of mandibular first molar are different in their morphology, and subgroups (1) and (2) indicated that the test results were slightly different. The root of premolar is straighter and thicker than the first molar. The two kinds of preparation methods can easily produce smooth and continuous cone-shaped root canals, and stress concentration is not easily produced. Therefore, the amount of dentin cutting becomes a major factor affecting root fracture resistance, so manual stainless steel instruments are more advantageous. In contrast, mesiodistal root canals of molars are relatively thin and curved in root tips, and the flexibility of manual stainless steel instruments is relatively poor, so weak parts and stress concentration areas are liable to be produced during root canal preparation. Manual stainless steel instruments may be liable for root fracture in comparison to Ni-Ti rotary instruments.

All references included in the present study utilized *in vitro* loading tests. The methods were simple, and the experiments can be easily repeated, thus they have become the main method for investigating the effects on the root strength of preparation by using different root canal preparation instruments. However, *in vitro* loading tests also have their limitations: the direction of forces in loading tests is single, the maximal load exceeds the physiological chewing force and it could not mimic the physiological force loading of teeth in oral cavity. However, the direction of forces on teeth is one of the important influencing factors for root fracture resistance and changes in loading direction may change the research results. Among all of the references included in the present study, the maximal loads of tooth roots

all exceeded the physiological chewing force in oral cavity. Direction^[29] and positions^[30] of forces may lead to significant effects on the test results. Lateral forces may be liable to cause stress concentration in teeth roots in comparison to vertical forces under the same loading conditions. Therefore, the seen root fracture in clinical practices is always induced by lateral stress. Meanwhile, high frequency of load may be produced when teeth play the role in chewing under physiological conditions, so the fatigue resistance of tooth also affect fracture resistance. The effects of different root canal preparation methods on root fracture resistance require more tests on lateral forces and fatigue tests.

The present study confirms that the effects of root canal preparation by Ni-Ti rotary instruments or manual stainless steel instruments on root fracture resistance are not statistically significant. These two preparation methods are both safe and effective if dentine is not excessively cut under normal chewing conditions.

COMMENTS

Background

Root canal therapy is a perfect treatment method for pulpitis and periapical disease. And root canal preparation is one of the key procedures for root canal therapy, which includes traditional hand stainless steel instruments preparation method and rotary nickel-titanium instruments preparation method. Rotary nickel-titanium instruments, which have excellent root shaping ability, ideal remotion ability and flexibility and high preparation efficiency are research hotspots. But many studies have shown that the teeth prepared by rotary nickel-titanium instruments may show an inclination towards longitudinal fissure, because more dentin is cut off.

Research frontiers

Many researches have carried out to study the different effects of two root canal preparation methods on root fracture resistance, but different results were obtained, which have led to puzzles in clinical operations for dentists.

Innovations and breakthroughs

Meta-analysis was done for the effect of root fracture of Ni-Ti rotary instruments and stainless steel hand instruments preparation methods. Meta-analysis provides a high quality system review.

Applications

The result can provide evidence for clinical therapy. Dentists can choose different root canal preparation methods according to the tooth type or tooth position and root curvatu.

Terminology

Meta-analysis is a quantitative statistical analysis of several separate but similar experiments or studies in order to test the pooled data for statistical significance.

Peer-review

This paper is potentially valuable.

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