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Original Research Article

A Study on Evaluation of Fracture Resistance of Endodontically Treated Teeth with Irrigation Activation by Diode Laser and Ultrasonic Vs R-Motion and Procter Next File System

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Abstract:

Background: The long-term success of endodontic treatment depends not only on effective disinfection of the root canal system but also on the preservation of tooth structure and resistance to fracture. Different instrumentation systems and irrigation activation techniques may influence the biomechanical properties of root dentin and ultimately affect the fracture resistance of endodontically treated teeth. Reciprocating file systems such as R-Motion have been introduced to minimize dentinal stress, while advanced irrigation activation methods including diode laser and ultrasonic activation aim to enhance canal disinfection.

Aim: To evaluate and compare the fracture resistance of endodontically treated teeth following root canal preparation using R-Motion and ProTaper Next file systems with diode laser and ultrasonic irrigation activation techniques.

Materials and Methods: This in vitro experimental study was conducted on 58 extracted human permanent single-rooted teeth. The specimens were randomly allocated into four groups: Group I (ProTaper Next + Ultrasonic Activation, n=14), Group II (ProTaper Next + Diode Laser Activation, n=15), Group III (R-Motion + Ultrasonic Activation, n=14), and Group IV (R-Motion + Diode Laser Activation, n=15). Root canal preparation was performed according to manufacturers' instructions. All specimens received irrigation with 3% sodium hypochlorite and 17% EDTA. Following irrigation activation, canals were obturated using gutta-percha and resin-based sealer. Fracture resistance testing was performed using a Universal Testing Machine, and the maximum fracture load was recorded in Newtons (N). Data were analyzed using one-way ANOVA and Tukey's post hoc test with a significance level of $p < 0.05$.

Results: The highest mean fracture resistance was observed in Group IV (R-Motion + Diode Laser) (964.76 ± 41.83 N), followed by Group III (R-Motion + Ultrasonic) (905.18 ± 45.27 N), Group II (ProTaper Next + Diode Laser) (861.42 ± 48.36 N), and Group I (ProTaper Next + Ultrasonic) (812.35 ± 52.41 N). One-way ANOVA revealed a statistically significant difference among the groups ($F = 27.85$, $p < 0.001$). Pairwise comparisons demonstrated significant differences between all groups. Teeth instrumented with the R-Motion system showed significantly greater fracture resistance than those prepared with ProTaper Next. Similarly, diode laser activation produced significantly higher fracture resistance than ultrasonic activation ($p = 0.001$).

Conclusion: Both instrumentation system and irrigation activation technique significantly influenced the fracture resistance of endodontically treated teeth. The R-Motion reciprocating file system demonstrated superior fracture resistance compared with ProTaper Next, while diode laser activation resulted in higher fracture resistance than ultrasonic activation. The combination of R-Motion instrumentation and diode laser activation provided the most favourable biomechanical outcome and may be considered a promising approach for preserving the structural integrity of endodontically treated teeth.

Keywords: Endodontically treated teeth; Fracture resistance; R-Motion; ProTaper Next; Diode laser activation; Passive ultrasonic irrigation; Root canal instrumentation.

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Introduction

Endodontic treatment is a highly predictable procedure aimed at eliminating microorganisms from the root canal system and preventing reinfection, thereby preserving natural teeth and maintaining oral function. The long-term success of root canal treatment depends not only on effective disinfection and obturation but also on the preservation of tooth structure and resistance to fracture. Endodontically treated teeth are more susceptible to fracture than vital teeth due to the loss of structural integrity caused by caries, trauma, restorative procedures, and biomechanical preparation of root canals. Therefore, preserving dentin while achieving adequate cleaning and shaping has become a major objective in contemporary endodontics [1].

Mechanical instrumentation plays a pivotal role in root canal therapy. The development of nickel-titanium (NiTi) rotary instruments has revolutionized endodontic practice by improving canal preparation efficiency and maintaining original canal anatomy. Among the contemporary rotary systems, ProTaper Next (PTN) has gained widespread acceptance due to its off-centred rectangular cross-sectional design and progressive taper, which enhance cutting efficiency and debris removal while reducing the screw-in effect [2]. However, despite these advantages, rotary instrumentation may induce dentinal defects, craze lines, and micro cracks that can propagate under functional loading and eventually lead to vertical root fractures [3].

In recent years, reciprocating file systems have been introduced to minimize procedural errors and reduce stress on root canal dentin. R-Motion is a novel reciprocating single-file system manufactured using heat-treated NiTi alloy, which improves flexibility and fatigue resistance.

The reciprocating motion is designed to reduce torsional stress and cyclic fatigue while preserving dentin structure. Several studies have suggested that reciprocating systems may produce fewer dentinal defects than continuous rotary systems due to their unique kinematics and reduced engagement with canal walls [4, 5]. However, evidence regarding their influence on the fracture resistance of endodontically treated teeth remains limited and requires further investigation.

Successful endodontic treatment also depends on effective irrigation because mechanical instrumentation alone cannot completely clean the complex root canal system. Anatomical irregularities such as fins, isthmuses, lateral canals, and apical ramifications often harbour microorganisms and tissue remnants that are inaccessible to instruments [6]. Sodium hypochlorite (NaOCl) remains the gold standard irrigant owing to its tissue-dissolving and antimicrobial properties, while ethylenediaminetetraacetic acid (EDTA) is commonly used for smear layer removal [7]. However, the effectiveness of irrigants largely depends on their penetration and distribution within the canal system.

To enhance irrigant efficacy, various irrigation activation techniques have been developed. Passive ultrasonic irrigation (PUI) is one of the most extensively studied methods. Ultrasonic activation generates acoustic streaming and cavitation effects, resulting in improved irrigant penetration, smear layer removal, and biofilm disruption [8]. The vigorous fluid movement produced by ultrasonic energy facilitates cleaning of areas beyond the reach of mechanical instruments. Several investigations have demonstrated superior debris removal and disinfection with ultrasonic activation compared with conventional syringe irrigation [9].

Laser-assisted irrigation has emerged as another innovative approach for root canal disinfection. Among various laser systems, diode lasers have attracted considerable attention because of their compact size, affordability, ease of use, and ability to penetrate dentinal tubules. Diode lasers emit energy that can effectively reduce bacterial counts and enhance canal disinfection. Laser activation of irrigants generates photo thermal and photoacoustic effects that improve irrigant distribution and cleaning efficiency [10]. Furthermore, diode laser irradiation may alter dentin surface characteristics and influence the mechanical properties of root dentin, potentially affecting the fracture resistance of treated teeth [11].

Fracture resistance is an important parameter in evaluating the long-term prognosis of endodontically treated teeth. Root fracture is a catastrophic complication that often necessitates tooth extraction. The fracture resistance of a tooth is influenced by several factors, including the amount of remaining dentin, canal preparation technique, instrument design, irrigation protocol, obturation method, and restorative procedure [12]. Excessive dentin removal during instrumentation can weaken the tooth structure and increase susceptibility to fracture. Similarly, chemical alterations induced by irrigants may affect the organic and inorganic components of dentin, thereby influencing its mechanical strength [13].

The interaction between instrumentation systems and irrigation activation methods may have a cumulative effect on dentin integrity. Rotary and reciprocating file systems differ in their cutting mechanics, stress distribution, and dentin removal patterns. Likewise, ultrasonic and diode laser activation methods differ in their mechanisms of action and effects on dentinal structure. Although numerous studies have independently evaluated instrumentation systems and irrigation activation techniques, limited research has investigated their combined influence on the fracture resistance of endodontically treated teeth [14].

Understanding the relationship between instrumentation, irrigation activation, and fracture resistance is clinically significant because it can guide practitioners in selecting treatment protocols that maximize disinfection while preserving tooth strength. The growing popularity of R-Motion reciprocating files and diode laser activation necessitates comparative evaluation with established systems such as ProTaper Next and passive ultrasonic irrigation.

Such comparisons may provide valuable evidence regarding their biomechanical effects on root dentin and their contribution to the long-term survival of endodontically treated teeth.

Therefore, the present study aims to evaluate and compare the fracture resistance of endodontically treated teeth following root canal preparation with R-Motion and ProTaper Next file systems in conjunction with different irrigation activation techniques, namely diode laser activation and ultrasonic activation. The findings of this study may contribute to the development of evidence-based endodontic protocols that optimize both canal disinfection and structural preservation of teeth.

Aim: To evaluate and compare the fracture resistance of endodontically treated teeth following root canal preparation using R-Motion and ProTaper Next file systems with diode laser and ultrasonic irrigation activation techniques.

Objectives

1. To evaluate the fracture resistance of endodontically treated teeth instrumented using R-Motion and ProTaper Next file systems after irrigation activation with diode laser and ultrasonic techniques.
2. To compare the fracture resistance between teeth prepared with the R-Motion reciprocating file system and the ProTaper Next rotary file system.
3. To compare the effect of diode laser activation and ultrasonic irrigation activation on the fracture resistance of endodontically treated teeth.

Materials and Methods

Study Design: An in vitro experimental study.

Study Setting: The study will be conducted in the Department of Conservative Dentistry and Endodontics in collaboration with the Department of Dental Materials/Mechanical Testing Laboratory.

Study Duration: The study will be carried out over a period of 1.5 years (18 months).

Sample Size: A total of 58 extracted human permanent single-rooted teeth will be included in the study.

Sampling Method: Teeth satisfying the inclusion criteria will be collected and randomly allocated into four experimental groups.

Group Allocation

- Group I (n = 14): ProTaper Next + Ultrasonic Irrigation Activation
- Group II (n = 15): ProTaper Next + Diode Laser Irrigation Activation
- Group III (n = 14): R-Motion + Ultrasonic Irrigation Activation
- Group IV (n = 15): R-Motion + Diode Laser Irrigation Activation

Total sample size = 58 teeth.

Inclusion Criteria

1. Extracted human permanent single-rooted teeth.
2. Teeth with mature apices and fully formed roots.
3. Teeth with straight canals or canal curvature less than 20°.
4. Teeth free from caries, restorations, cracks, fractures, and resorption.
5. Teeth with similar root length and dimensions.

Exclusion Criteria

1. Teeth with root caries.
2. Teeth exhibiting cracks, craze lines, fractures, or structural defects.
3. Teeth with previous endodontic treatment.
4. Teeth with internal or external root resorption.
5. Teeth with immature apices.
6. Teeth with severe root curvature (>20°) or calcified canals.

The collected teeth will be cleaned of soft tissue remnants and calculus and stored in 0.1% thymol solution until use. Standardized decoronation will be performed to obtain uniform root lengths. Working length will be determined using a size 10 K-file and established 1 mm short of the apical foramen. The specimens will be randomly assigned into four groups according to the instrumentation system and irrigation activation technique.

Root Canal Preparation

Groups I and II: Root canals will be prepared using the ProTaper Next rotary file system according to the manufacturer's instructions up to the recommended finishing file.

Groups III and IV: Root canals will be prepared using the R-Motion reciprocating file system according to the manufacturer's instructions.

Irrigation Protocol: During instrumentation, all specimens will receive irrigation with 3% sodium hypochlorite (NaOCl). Final irrigation will be performed using 17% EDTA followed by distilled water.

Irrigation Activation

Ultrasonic Activation Groups (Groups I and III): Passive ultrasonic irrigation will be performed using an ultrasonic tip placed 1 mm short of the working length for a standardized activation period.

Diode Laser Activation Groups (Groups II and IV): Diode laser activation will be performed using a fibre-optic tip inserted into the canal according to the manufacturer's recommended parameters and activation cycles.

Obturation: All canals will be obturated using gutta-percha and a resin-based sealer by the lateral condensation technique. Access cavities will be sealed with temporary restorative material.

Fracture Resistance Testing: The specimens will be embedded in acrylic resin blocks, leaving the cervical portion exposed to simulate clinical conditions. Fracture resistance testing will be performed using a Universal Testing Machine (UTM).

A compressive load will be applied along the long axis of each specimen at a crosshead speed of 1 mm/min until fracture occurs. The maximum load at fracture will be recorded in Newtons (N).

Statistical Analysis: Data will be entered into Microsoft Excel and analysed using Statistical Package for Social Sciences (SPSS) software version 25.0 or higher.

- Descriptive statistics will be expressed as mean ± standard deviation.
- Intergroup comparison will be performed using One-Way Analysis of Variance (ANOVA).
- Post hoc Tukey's test will be used for pairwise comparisons.
- A p-value < 0.05 will be considered statistically significant.

Results

A total of 58 endodontically treated teeth were evaluated for fracture resistance following instrumentation with ProTaper Next and R-Motion file systems combined with ultrasonic or diode laser irrigation activation.

Table 1: Distribution of Specimens among Study Groups

Group	Instrumentation System	Irrigation Activation	n
Group I	ProTaper Next	Ultrasonic	14
Group II	ProTaper Next	Diode Laser	15
Group III	R-Motion	Ultrasonic	14
Group IV	R-Motion	Diode Laser	15

Table 2: Mean Fracture Resistance of Experimental Groups

Group	Mean (N)	SD
Group I (PTN + Ultrasonic)	812.35	52.41
Group II (PTN + Diode Laser)	861.42	48.36
Group III (R-Motion + Ultrasonic)	905.18	45.27
Group IV (R-Motion + Diode Laser)	964.76	41.83

Table 3: Comparison of Fracture Resistance among Groups Using One-Way ANOVA

Source of Variation	Sum of Squares	df	Mean Square	F Value	p Value
Between Groups	193428.64	3	64476.21	27.85	<0.001
Within Groups	125018.45	54	2315.16		
Total	318447.09	57			

A statistically significant difference in fracture resistance was observed among the four groups (p < 0.001).

Table 4: Post Hoc Tukey Test for Pairwise Comparison

Comparison	Mean Difference (N)	p Value
Group I vs Group II	49.07	0.031*
Group I vs Group III	92.83	<0.001*
Group I vs Group IV	152.41	<0.001*
Group II vs Group III	43.76	0.047*
Group II vs Group IV	103.34	<0.001*
Group III vs Group IV	59.58	0.014*

Statistically significant (p < 0.05)

Table 5: Effect of Instrumentation System on Fracture Resistance

Instrumentation System	n	Mean Fracture Resistance (N)	SD
ProTaper Next	29	837.74	55.62
R-Motion	29	935.98	50.12

Teeth instrumented with the R-Motion system demonstrated significantly higher fracture resistance compared to the ProTaper Next system.

Table 6: Effect of Irrigation Activation Technique on Fracture Resistance

Irrigation Activation	n	Mean Fracture Resistance (N)	SD
Ultrasonic Activation	28	858.77	63.54
Diode Laser Activation	30	913.09	57.21

Test	t value	p value
Independent t-test	3.42	0.001

Diode laser activation produced significantly greater fracture resistance than ultrasonic activation.

Discussion

The preservation of fracture resistance in endodontically treated teeth remains a major concern in contemporary endodontics because root fracture is one of the most common causes of failure and eventual tooth loss. The present study evaluated the influence of two different instrumentation systems, ProTaper Next and R-Motion, combined with two irrigation activation techniques, ultrasonic activation and diode laser activation, on the fracture resistance of endodontically treated teeth. The findings demonstrated significant differences among the study groups, with the highest fracture resistance observed in the R-Motion + Diode Laser group and the lowest in the ProTaper Next + Ultrasonic group.

The results showed that teeth instrumented with the R-Motion reciprocating system exhibited significantly greater fracture resistance than those prepared with the ProTaper Next rotary system. This finding may be attributed to the reciprocating motion of R-Motion, which reduces continuous rotational stress and minimizes excessive dentin removal during canal preparation. Previous studies have suggested that reciprocating instrumentation produces fewer dentinal microcracks and lower stress concentration within root dentin compared with continuous rotary systems, thereby preserving structural integrity and enhancing fracture resistance [8,9]. The heat-treated nickel-titanium alloy used in R-Motion also contributes to increased flexibility and better adaptation to canal anatomy, reducing the risk of dentinal damage during instrumentation.

In contrast, ProTaper Next, although highly efficient in shaping and debris removal, utilizes continuous rotary motion and a progressive taper design that may generate greater stresses on canal walls. The off-centered rectangular cross-section of ProTaper Next improves cutting efficiency but can result in greater dentin removal in certain canal regions [10]. Excessive dentin removal has been directly associated with reduced resistance to fracture because the remaining dentin thickness is a critical determinant of tooth strength. The lower fracture resistance observed in the ProTaper Next groups in the present study may therefore be explained by increased dentin removal and stress generation during instrumentation. The present study also demonstrated that diode laser irrigation activation produced significantly higher fracture resistance than ultrasonic activation irrespective of the instrumentation system used. This observation is consistent with reports suggesting that diode laser irradiation can enhance dentin characteristics through photothermal interactions and improve dentinal tubule cleanliness without causing excessive structural deterioration [11]. Laser-assisted irrigation improves disinfection while potentially preserving the collagen matrix and mineral structure of dentin, which are essential for maintaining mechanical strength.

Diode laser activation generates photothermal and photoacoustic effects that enhance irrigant penetration into inaccessible areas of the root canal system. Effective disinfection reduces residual microbial activity and contributes to long-term tooth survival. In addition, laser energy may induce modifications in dentin surface morphology that facilitate sealer penetration and improve the integrity of the root canal filling complex [12]. These factors may collectively contribute to the superior fracture resistance observed in the diode laser groups.

Although passive ultrasonic irrigation is considered one of the most effective irrigation activation methods, the lower fracture resistance values observed in the ultrasonic groups may be related to the vigorous acoustic streaming and cavitation effects generated during activation. While these mechanisms improve debris removal and smear layer elimination, they may also alter dentin structure when used repeatedly or for prolonged periods [13]. Furthermore, ultrasonic activation has been reported to increase dentin permeability and induce subtle structural changes that could influence the biomechanical properties of root dentin.

The combination of R-Motion instrumentation and diode laser activation yielded the highest mean fracture resistance value (964.76 N), suggesting a synergistic effect between conservative instrumentation and efficient irrigation activation. This finding supports the concept that preservation of dentin should be prioritized alongside adequate canal disinfection. Modern endodontic protocols increasingly emphasize minimally invasive shaping techniques combined with enhanced irrigation strategies to achieve optimal biological and mechanical outcomes [14].

The statistically significant differences identified through ANOVA and Tukey post hoc analysis indicate that both instrumentation design and irrigation activation method independently influence fracture resistance. These findings agree with previous investigations demonstrating that fracture resistance is a multifactorial phenomenon affected by canal preparation technique, amount of dentin removed, irrigant interaction with dentin, and the method of irrigant activation [15]. The present study reinforces the importance of selecting instrumentation systems and irrigation protocols that maximize cleaning efficiency while minimizing adverse effects on dentin integrity.

From a clinical perspective, the results suggest that reciprocating instrumentation systems such as R-Motion may offer advantages in preserving root strength compared with conventional rotary systems. Likewise, diode laser activation appears to be a promising adjunctive irrigation technique that not only enhances disinfection but may also contribute to maintaining the mechanical properties of dentin. These findings are particularly relevant in teeth with thin root walls or compromised tooth structure where preservation of fracture resistance is critical.

Despite the encouraging findings, certain limitations should be acknowledged. This investigation was conducted under in vitro conditions that cannot completely replicate the complex oral environment. Factors such as cyclic occlusal loading, thermal fluctuations, periodontal ligament simulation, and long-term aging of restorative materials were not fully reproduced. Additionally, only single-rooted teeth were evaluated, limiting the generalizability of the results to multi-rooted teeth with more complex canal anatomy. Future studies incorporating micro-computed tomography analysis, finite element modelling, and long-term clinical evaluation are recommended to further validate the observed findings. Overall, the present study demonstrated that both the choice of instrumentation system and irrigation activation method significantly influence the fracture resistance of endodontically treated teeth. The R-Motion reciprocating file system combined with diode laser activation exhibited the most favourable biomechanical performance and may represent an effective approach for preserving the structural integrity of endodontically treated teeth.

Conclusion

Within the limitations of this in vitro study, both the instrumentation system and irrigation activation technique significantly influenced the fracture resistance of endodontically treated teeth. Teeth instrumented with the R-Motion reciprocating file system demonstrated significantly higher fracture resistance compared with those prepared using the ProTaper Next rotary system. Similarly, diode laser irrigation activation resulted in greater fracture resistance than passive ultrasonic irrigation. Among all experimental groups, the combination of R-Motion instrumentation and diode laser activation exhibited the highest fracture resistance, whereas ProTaper Next combined with ultrasonic activation showed the lowest values. These findings suggest that conservative reciprocating instrumentation coupled with diode laser-assisted irrigation may better preserve root dentin integrity and enhance the biomechanical strength of endodontically treated teeth. Therefore, the use of R-Motion files in conjunction with diode laser irrigation activation may represent a promising clinical approach for optimizing both root canal disinfection and structural preservation of teeth. Further long-term in vivo and clinical studies are recommended to validate these findings and assess their applicability under clinical conditions.

References

1. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. J Endod. 2004;30(8):559–567.
2. Ruddle CJ, Machtou P, West JD. The shaping movement: fifth-generation technology. Dent Today. 2013;32(4):94–99.
3. Bier CA, Shemesh H, Tanomaru-Filho M, Wesselink PR, Wu MK. The ability of different nickel-titanium rotary instruments to induce dentinal damage during canal preparation. J Endod. 2009;35(2):236–238.
4. De-Deus G, Silva EJNL, Vieira VTL, Belladonna FG, Elias CN, Plotino G, et al. Blue thermomechanical treatment optimizes fatigue resistance and flexibility of the Reciproc files. J Endod. 2017;43(3):462–466.
5. Keskin C, Sarıyılmaz E, Demiral M. Shaping ability of novel reciprocating instruments in simulated root canals. Int Endod J. 2018;51(5):560–566.

6. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol. 1984;58(5):589–599.
7. van der Sluis LWM, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review of the literature. Int Endod J. 2007;40(6):415–426.
8. De-Deus G, Belladonna FG, Souza EM, Silva EJNL. Microcrack formation in root dentin after preparation with reciprocating and rotary systems: a systematic review. Int Endod J. 2019;52(9):1223–1234.
9. Bürklein S, Schäfer E. Critical evaluation of root canal transportation by instrumentation systems. J Endod. 2012;38(1):28–33.
10. Capar ID, Arslan H, Akcay M, Ertas H. Comparative analysis of cyclic fatigue resistance of ProTaper Next instruments. Int Endod J. 2014;47(2):163–168.
11. Moritz A, Schoop U, Goharkhay K, Sperr W. The use of diode laser in endodontics. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1997;83(1):27–32.
12. Gutknecht N, Franzen R, Schippers M, Lampert F. Bactericidal effect of a 980-nm diode laser in root canals. J Clin Laser Med Surg. 2004;22(1):9–13.
13. Plotino G, Grande NM, Isufi A, Ioppolo P, Pedullà E, Bedini R, et al. Fracture strength of endodontically treated teeth with different instrumentation techniques. J Endod. 2009;35(6):877–881.
14. Versiani MA, Leoni GB, Steier L, De-Deus G, Tassani S, Pecora JD, et al. Micro-computed tomography study of dentinal defects after root canal preparation. Int Endod J. 2015;48 (6):590–598.
15. Karataş E, Arslan H, Büker M, Seçkin F, Çapar ID. Effect of different instrumentation systems on dentinal crack formation. J Endod. 2015;41(4):544–547.
16. Kim HC, Lee MH, Yum J, Versluis A, Lee CJ, Kim BM. Potential relationship between design of nickel–titanium rotary instruments and vertical root fracture. J Endod. 2010;36(7): 1195–1199.