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DOES REDUCED TAPER CANAL PREPARATION INCREASE THE LOAD CAPACITY OF ENDODONTICALLY TREATED TEETH?

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Objectives: The aim of this in-vitro study is to assess and compare the load capacity of teeth with canals prepared using progressive taper versus regressive taper.

Methods: Twenty-seven extracted mandibular molars were categorized into three equal groups. The negative control group involved teeth that were accessed and restored with composite resin without canal preparation. The regressive canal preparation group used the TruNatomy file system, while the progressive canal preparation group employed the ProTaper Gold system. Subsequently, all samples underwent loading using a universal testing machine until tooth fracture occurred. The force required to fracture each tooth was recorded in Newton.

Results: The highest value was found in samples without preparation 1009.68±57.28 N, followed by TN group 979.04±31.16 N, while the lowest value was found in PTG 966.47±17.51N. There was no significant difference between different groups (p=0.118).

Conclusions: The root canal taper did not exert a significant influence on the longevity or fracture resistance of the tooth.

Keywords: root canal taper, rotary nickel titanium, load capacity, fracture resistance

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Conflicts of interest:
The authors declare no conflicts of interest.

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LA PRÉPARATION RÉDUITE DU CANAL CONIQUE AUGMENTE-T-ELLE LA CAPACITÉ DE CHARGE DES DENTS TRAITÉES ENDODONTIQUEMENT ?

Objectifs: Le but de cette étude in vitro est d'évaluer et de comparer la capacité de charge des dents avec des canaux préparés par cône progressif par rapport au cône régressif.

Méthodes: Vingt-sept molaires mandibulaires extraites ont été classées en trois groupes égaux. Le groupe témoin négatif comprenait des dents accessibles et restaurées avec de la résine composite sans préparation canalaire. Le groupe de préparation canalaire régressive a utilisé le système de limes TruNatomy, tandis que le groupe de préparation canalaire progressive a utilisé le système ProTaper Gold. Par la suite, tous les échantillons ont été soumis à une mise en charge à l'aide d'une machine de test universelle jusqu'à ce qu'une fracture dentaire se produise. La force nécessaire pour fracturer chaque dent a été enregistrée en Newton.

Résultats: La valeur la plus élevée a été trouvée dans les échantillons sans préparation 1009,68 ± 57,28 N, suivie par le groupe TN 979,04 ± 31,16 N, tandis que la valeur la plus faible a été trouvée dans le PTG 966,47 ± 17,51 N. Il n'y avait pas de différence significative entre les différents groupes (p = 0,118).

Conclusions: La conicité canalaire n'a pas exercé d'influence significative sur la longévité ou la résistance à la fracture de la dent.

Mots-clés: cône canalaire, nickel-titane rotatif, capacité de charge, résistance à la fracture

Introduction

The concept of minimally invasive endodontics primarily targets the preservation of tooth structure to mitigate the risk of vertical root fracture following endodontic treatment [1]. This approach is perceived as yielding favorable outcomes, particularly in delivering patient-centered results [2]. However, despite the noble intentions behind this objective, it remains, at present, a hypothesis awaiting empirical evidence.

The concept was formulated based on the premise that the preservation of the pericervical dentine, commonly referred to as a critical zone, is essential [1]. It is asserted that maintaining this dentin during access cavity preparation and canal shaping will augment the tooth's resistance to fracture. While it is clinically logical to avoid unnecessary removal of tooth structure during root canal treatment [3], the minimally invasive concept, which specifically advocates for the preservation of pericervical dentin, remains a hypothesis that has not undergone comprehensive testing.

In line with the principles of minimally invasive endodontics, rotary nickel-titanium systems, such as TruNatomy (Dentsply Sirona), have been introduced to the market. These systems feature a regressive taper, characterized by a maximum flute diameter of 0.8 mm at the largest point. The claim is that this design preserves pericervical dentin, thereby enhancing the fracture resistance of teeth following endodontic treatment [4].

Several studies have explored the impact of taper on the fracture resistance of endodontically treated teeth [5-8]. Nevertheless, there is currently no in-vitro study specifically examining the comparative effects of progressive taper versus regressive taper on the loading capacity of endodontically treated teeth.

The objective of this in-vitro study is to assess and compare the load capacity of teeth after shaping root canals prepared using progressive or regressive taper instruments.

Materials and Methods

The study was conducted in accordance with the Declaration of Helsinki and approved by the research ethics committee Faculty of Dentistry at The British University in Egypt (FD BUE REC 21-037).

A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference in the loading capacity of tooth structure between molars prepared using different root canal tapers. By adopting an alpha level of (0.05) a beta of (0.2) i.e., power=80% and an effect size (f) of (0.75) calculated based on the results of Sabeti et al., 2018 [5]; the predicted sample size (n) was a total of 21 teeth. Sample size will be increased by 30% to compensate for possible failure in samples during testing to be 27 teeth. Sample size calculation was performed using G*Power version 3.1.9.7.

Samples collection and preparation

Twenty-seven recently extracted sound permanent human first and second mandibular molars were collected for the study. The teeth were obtained from the Oral Surgery Department, Faculty of Dentistry, and extracted due to periodontal diseases. Teeth were cleaned from hard and soft debris using ultrasonic scaler (Woodpecker, Guilin Woodpecker Medical Instrument Co., China). Subjected samples were recently extracted with intact mature apices and normal root morphology. The teeth have non-carious lesions or minimal fissure caries and having mesial roots with maximal curvature of 2. Collected teeth were examined under 12.5x magnification (ZEISS EXTARO 300, Carl Zeiss Meditec AG, Germany) and transillumination to detect any cracks. Teeth showing fractures, cracks, craze lines, previous filling, previous root-canal treatment, root resorption, and root canal calcification were excluded from the pool of samples and replaced. Standardized digital radiographs were acquired and transferred to AutoCAD 2008 (Autodesk, San Rafael, CA, USA) to determine the angle and radius of canals curvature as described previously [9]. Only teeth whose radii of curvature ranged between 4 and 9 mm and whose angles of curvature ranged between 15° and 25° were included. Samples were preserved in 0.9% physiological saline solution at room temperature.

Samples grouping

Pre-operative radiograph was taken for all samples, then all samples (N=27) were subjected to anatomical balanced distribution into three equal groups: negative control group (NC), ProTaper Gold system group (PTG) and TruNatomy system group (TN).

Access cavity preparation, root canal instrumentation and obturation

Conventional access cavity preparation [10] was performed in all teeth using round carbide burs (MANI, INC. Japan) for intital pulp chamber penetration and Endo-Z bur (Densply-Maillefer) for lateral extension of the access cavity and pulp chamber wall flaring, The burs were mounted in a high high-speed-piece (Sirona T3 Racer highspeed, Dentsply Sirona, Germany), and access cavity was done under coolant.

After coronal access cavity preparation, canals were negotiated until patency with a #10 K-file (MANI, INC. Japan). Working length was determined by inserting a #10 K-file until its tip was flushed with the root apex, then subtracting 1 mm and recorded as the working length of each canal. Reproducible glide path was then achieved until the #10 file was loose.

In the NC group, the coronal access cavity was restored by direct bonded composite resin restoration (3M Z250, ESPE, USA).

In the PTG group, manufacturing instructions for canal instrumentation were followed in the subsequent sequence: initially, the coronal two-thirds of the canals were scouted until encountering resistance, using a #15 K-file. Subsequently, the canals were shaped with an S1 (18.02v) instrument until the depth of a #15 hand file was reached, followed by the utilization of an S2 (20.04v) instrument on the same canal's two-thirds length. Following this, the apical one-third was scouted and enlarged with a #15 K-file until it was loose to the full working length. Subsequently, an S1 file was employed in a brushing action until the working length followed by the S2 instrument. Canal preparation was finished using the F1 (20.07v), followed by F2 (25.08v) finishing files to working length in the similar recommended brushing motion. Apical gauging with a #25 K-file to confirm enlarging the canals to the appropriate width, and if #25 K-file was loose, further enlargement with F3 (30.09v) file performed. Between each file size, canal's patency was checked with #10 K-file, and irrigation with 2 ml of NaOCl was delivered with TruNatomy irrigation needle.

Considering TN group, root canal preparation adhered also to its recommended manufacture instruction. Firstly, coronal modification using TruNatomy Orifice Modifier (20.08) was advanced in an apical direction for only 2-3 gentle amplitudes approximately 2-5 mm in-and-out of the canal until reaching the coronal two-third of the canal. Then the canal patency was checked and confirmed before creating and confirming a reproducible glide path using a TruNatomy Glider (17.02v) in an apical direction for only 2-3 gentle amplitudes approximately 2-5 mm in-and-out of the canal. Afterward canal shaping with the TruNatomy Prime file (26.04v) which was used passively in the presence of irrigant with no more than 2-3 gentle amplitudes approximately 2-5 mm in-and-out of the canal. Irrigation, cleaning cutting flutes and then repeated insertion of the Prime were not executed until the working length was reached.

The rotary motor Xsmart IQ (Dentsply Sirona) was used in both group with each file recommended torque and rpm.

After root canal preparation in both groups, root canals were dried with matching size paper points, followed by radiographic cone check in each canal with corresponding Comfort Fit matching cone. Root canal obturation was carried with AH plus Bioceramic sealer (Dentsply Sirona), where the 24-gauge tip was inserted no further than to the middle third of the root canal. Sealer was then injected into the root canal until it is visible at the root canal orifice. The master cone was inserted into the root canal and pushed to the working length. The coronal portion of the master cone was cut at the root canal orifice using Gutta Smart heat plugger, then compacted with an appropriately sized pre-fitted plugger.

The access of all samples was then restored similarly to the NC, and teeth were preserved at 37°C for a week to ensure sealer setting, approximately 2-4 hours according to the manufacturer's instructions, before preserving them in 0.9% physiological saline solution at room temperature.

Sample preparation for testing

Prior loading capacity testing, The root of each specimen was covered with a 0.3mm thick high fusion wax (CAVEX® GmbH & Co., Germany) to simulate the periodontal ligament and embedded into acrylic resin (Sofa Dental, Kerr Co., Germany) to simulate the alveolar bone [11].

Load capacity testing

Each acrylic block was positioned and stabilized on the lower plate of a universal testing machine (Lloyd LR 5K, UK) to allow the stainless steel spherical tip with a diameter of 5 mm to be positioned at the central fossa. The load was applied at a crosshead with speed 1mm/minute until fracture occurred, the force required to fracture to occur was recorded in Newton (N).

Statical analysis

To analyze the results, statistical software (SPSS 17; SPSS Inc, Chicagi, IL) was used. ANOVA test and the Tukey post hoc multi-comparison analysis were used to compare all groups in order to determine any statistically significant difference. For all comparisons, the level of significance was set at $p<0.05$.

Results

Table 1 represents the load capacity in each group, which is the force required to fracture each sample.

There was no significant difference between different groups ($p=0.118$). The highest value was found in samples without preparation (1009.68±57.28), followed by TN group (979.04±31.16), while the lowest value was found in PTG (966.47±17.51).

Table 1: Descriptive statistics of load capacity (N) for different groups

Group	Mean	95% confidence interval		SD	Min	Max
		Lower	Upper			
No preparation	1009.68	972.26	1047.11	57.28	909.30	1092.40
PTG	966.47	955.03	977.91	17.51	948.74	999.80
TN	979.04	958.68	999.40	31.16	940.24	1015.80

Discussion

Since the introduction of nickel-titanium (NiTi) instruments for mechanical root canal enlargement in the 1990s, the focus of root canal preparation techniques has been on creating tapered shapes to facilitate effective cleaning, disinfection, and filling procedures. Clark and Khademi proposed a novel model for access opening and coronal preparation with the aim of reducing the incidence of vertical root fractures in endodontically treated teeth (1). Their approach centered on preserving the pulp chamber roof and the pericervical dentin (PCD), which constitutes an area located approximately 4 mm above and 4 mm below the crestal bone.

Over the years, this foundational concept of dentin preservation has evolved to encompass various aspects of root canal treatment. This comprehensive approach is now recognized as minimally invasive endodontics, a concept that extends beyond the preservation of sound tooth structure not only in relation to access cavity opening but also to root canal preparation [12, 13]. One of the major factors driving this concept is the impact of social media on endodontic perception and practice [14].

The minimally invasive approach applied to root canal preparation aims to conserve a greater amount of dentin in the pericervical region and incorporates the use of low-tapered instruments for shaping. In recent years, several companies have introduced new NiTi systems with smaller dimensions (tip and taper) to achieve this objective [5, 15]. One such example is the TruNatomy rotary system (Dentsply Sirona, Ballaigues, Switzerland), which consists of instruments made from NiTi wire with a maximum fluted diameter of 0.8 mm to maximize PCD preservation and avoid overflaring of the canal preparation.

The objective of this study aimed to assess the loading capacity of endodontically treated teeth by contrasting the minimally invasive canal preparation approach offered by the TruNatomy regressive taper file system with the progressive taper system provided by ProTaper Gold.

As the majority of our existing knowledge regarding fracture resistance of teeth primarily originates from laboratory-based research, the translation of these findings into clinical practice necessitates a prudent approach. It is important to acknowledge that the quest for an almost perfect design remains ongoing. It is crucial to avoid the misconception that an experimental model should aim to faithfully replicate clinical conditions, as this notion is fundamentally flawed, given that benchtop studies cannot entirely replicate the complexities of clinical settings. Instead, researchers should meticulously scrutinize and manage any potential sources of bias to create optimal conditions for isolating the specific variable of interest during experiments.

One of the pivotal methodological considerations in research design pertains to the establishment of a dependable baseline, given that anatomical variations in the sampled specimens can exert a direct influence on the study's outcomes. It appears intuitive that the precise anatomical matching of teeth allocated to each experimental group could potentially reduce bias into the ultimate conclusions, it is noteworthy that several like the one presented here, have conducted sample selection using radiographic examination [16, 17] and external measurements of teeth, thus minimizing the intrinsic anatomical heterogeneity of teeth [15] and improving the internal validity of the study [18].

In the field of endodontic research, there exists a prevailing notion that a robust experimental model should faithfully replicate the clinical scenario. An illustrative case in point is the argument put forth suggesting that conventional static loading tests should be supplanted since in clinical practice, the majority of failures stem from cyclic fatigue at subcritical loads, significantly lower than the load capacity [19]. However, this assertion lacks empirical validation for the proposed methodology and recommends that future investigations in this domain should exclusively employ the cyclic fatigue approach, also known as dynamic loading tests, to assess the fracture resistance of teeth. While this proposition may seem logical, it is imperative to bear in mind that loading tests are not designed to faithfully replicate clinical conditions. Instead, they are crafted to facilitate a precise comparison of the limited resistance capabilities of a given material, technique, or scenario under rigorously controlled ex vivo conditions. In doing so, they offer a reliable and reproducible means to rank materials and techniques with low ethical costs, expeditiously, and cost-effectively. Thus, the primary objective of an ideal preclinical laboratory study, closely aligned with real-world applications [20], is to provide a means of reasonably predicting the clinical performance of materials and techniques. In pursuit of this goal, it is not obligatory to faithfully reproduce the intricacies of the clinical setting.

In line with previous laboratory investigations, the study by Sabeti et al. [5] did not observe a substantial mechanical distinction between root canal tapers. Specifically, the .04 and .06 taper groups did not exhibit significant differences. A parallel conclusion was reached in another in vitro study conducted by the Turkish research group [21]. Both of these aforementioned studies further indicated that transitioning to a .08 taper resulted in a statistically significant reduction in tooth fracture resistance.

While our study employed variable tapers, in contrast to the previously mentioned investigations, it yielded similar findings. Specifically, our study concluded that the enlargement of the PCD area achieved by PTG instruments, did not exert a significant influence on tooth fracture resistance. These results challenge the prevailing notion that minimally invasive files, characterized by reduced maximum flute diameter and consequent minimal dentin removal from the PCD area, should be adopted as standard practice.

In line with our findings, an additional body of research, employing Finite Element Analysis (FEA), has been conducted to address the same hypothesis regarding the PCD. Elkholy et al. [22] employed FEA to specifically isolate the effects of root canal preparation methods, comparing (TN) and (PTG). Their study revealed no significant difference in the lifespan of the endodontically treated tooth or the maximum stresses generated when comparing these two canal tapers.

Furthermore, another FEA investigation [23] explored the significance of pericervical dentin after coronal canal flaring in the biomechanical behavior and lifespan of a maxillary molar. Even when employing aggressive techniques like Gates Glidden for coronal preparation of the root canal, this study found that it did not have a significant effect on the root's biomechanical behavior or its lifespan.

Conversely, a solitary (FEA) investigation revealed contrasting results. Under the constraints of this study, it is apparent that the maximum stress levels within the tooth subjected to ProTaper Gold preparation exceeded those within the tooth prepared using the V-Taper 2H system, a regressive taper system [24]. A limitation of this study is that it employed two distinct, pre-existing, and already shaped models for stress simulation, whereas the preceding two studies utilized a consistent tooth model to assess the impact of the preparation method. However, minimum canal shaping may be recommended for shaping middle mesial canals in terms of canal taper and apical diameter [25].

In a separate investigation, the primary objective was to assess the preservation of periradicular dentin and the apical canal enlargement in mandibular molars using TruNatomy and ProTaper Gold instruments. The findings revealed that both TruNatomy and ProTaper Gold proved to be effective in conducting canal preparation in mandibular molars. In terms of maintaining untouched canal walls and preserving remaining dentin thickness, the tested systems exhibited substantial similarities. There were marginal differences observed in the apical transportation of mesial canals and the extent of dentin removal at the coronal third, but these variations did not result in clinically significant errors [26], and that explains why both regressive taper and progressive taper root canal preparation did not affect the loading capacity of the endodontically treated teeth.

There is a growing body of evidence suggesting that the biomechanical behaviour and fatigue life of endodontically treated teeth is mainly influenced by the relation between the location of occlusal load points and the extent of the access cavity margins [22, 27, 28]. This implies that the extent or taper of root canal preparation is a minor player compared to the size, extension, and marginal ridges involvement of the access cavity preparation [29].

Conclusion

According to the findings of the conducted investigation into minimal invasive root canal preparation, it is evident that under controlled conditions, the root canal taper did not exert a significant influence on the longevity or fracture resistance of the tooth. These results challenge the previously hypothesized concept of pericervical dentin preservation, which had been considered only a theoretical proposition and did not withstand empirical testing.

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