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Comparative evaluation of fracture resistance of endodontically treated maxillary premolars restored with post-and-core vs. post-and-core with full-coverage crown: an in-vitro study

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Abstract

INTRODUCTION. The extensive loss of coronal and radicular tooth structure, changes to dentin characteristics, and biomechanical constraints make endodontically treated teeth (ETT) more prone to fractures. Prosthodontic rehabilitation, including post-and-core systems and full-coverage crowns, is a standard approach to restore their function and structural integrity. However, a clear, stepwise comparison of the fracture resistance imparted by endodontic treatment alone versus subsequent stages of prosthodontic restoration is needed to guide clinical decision-making.

MATERIALS AND METHODS. Forty extracted human maxillary premolars of similar dimensions were selected and randomly allocated into four groups (n = 10): Group I (Control) – intact sound teeth; Group II (ETT) – endodontically treated teeth with access cavities left unrestored; Group III (ETT + PC) – endodontically treated, restored with a fiber post and composite core; and Group IV (ETT + PC + C) – endodontically treated, restored with a fiber post, composite core, and a full-coverage cast metal crown. After the specimens underwent thermocycling, they were placed in acrylic resin blocks that included a periodontal ligament simulation. Until fracture occurred, a universal testing machine was used to apply a compressive force at a speed of 1 mm/min to the central fossa of each tooth, which was angled at 90 degrees to the occlusal plane. It was noted the maximum load at crack (in Newtons, N). The data was examined with the use of Tukey's post hoc test ($\alpha = 0.05$) and one-way ANOVA.

RESULTS. The average fracture resistance values (± standard deviation) for the four groups were as follows: 1650.5 ± 180.2 N for Group I, 615.8 ± 95.4 N for Group II, 950.3 ± 110.7 N for Group III, and 1425.6 ± 155.1 N for Group IV. Statistical analysis using one-way ANOVA showed that there was a notable difference between the several groups ($p < 0.001$). Every group except Group I (intact) was much weaker. Group IV (ETT + PC + C) showed a noticeably greater resistance to fracture compared to Group II (ETT) and Group III (ETT + PC) ($p < 0.05$). In comparison to Group II, Group III was likewise much stronger ($p < 0.05$). The fracture resistance of Group IV was still noticeably lower than the intact control group ($p < 0.05$), nevertheless.

CONCLUSIONS. For premolars, the fracture resistance is significantly reduced only by preparing the endodontic access. Placing a full-coverage crown is necessary to provide a major strengthening of the tooth structure, while adding a post-and-core gives a small improvement in strength. But, the strength of an unbroken tooth when it was first cracked is not entirely restored by modern restorative procedures.

Keywords: endodontic treatment, prosthodontic restoration, post-and-core, fracture strength, In-vitro study, biomechanics

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Сравнительная оценка прочности на разрушение эндодонтически обработанных верхних премоляров, восстановленных системой штифт-накопитель и системой штифт-накопитель с коронкой полной облицовки: лабораторное исследование

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Резюме

ВВЕДЕНИЕ. Широкая потеря коронковой и корневой ткани зуба, изменения характеристик дентина и биомеханические ограничения делают эндодонтически обработанные зубы (ETT) более восприимчивыми к переломам. Протезное восстановление, включая системы штифт-накопитель и коронки полной облицовки, является стандартным подходом для восстановления их функции и структурной целостности. Тем не менее, требуется четкое поэтапное сравнение прочности на разрушение после только эндодонтического лечения и последующих стадий протезного восстановления для обоснованного принятия клинических решений.

МАТЕРИАЛЫ И МЕТОДЫ. Было отобрано 40 экстрагированных верхних премоляров человека с сопоставимыми размерами, которые случайным образом распределили на четыре группы (n = 10): группа I (контроль) – интактные зубы; группа II (ETT) – эндодонтически обработанные зубы с оставленными без реставрации полостями доступа; группа III (ETT+PC) – эндодонтически обработанные зубы, восстановленные с использованием волоконного штифта и композитного накопителя; группа IV (ETT+PC+C) – эндодонтически обработанные зубы, восстановленные волоконным штифтом, композитным накопителем и коронкой полной облицовки из металла. После термоциклирования образцы фиксировали в блоках из акриловой смолы с имитацией периодонтальной связки. С помощью универсальной испытательной машины на центральную фоссу каждого зуба под углом 90° к окклюзионной плоскости наносили сжимающую нагрузку со скоростью 1 мм/мин до момента разрушения. Фиксировали максимальную нагрузку до появления трещины (в Ньютонах, N). Данные анализировали с использованием однофакторного дисперсионного анализа (ANOVA) и последующего теста Тьюки (α = 0,05).

РЕЗУЛЬТАТЫ. Средние значения прочности на разрушение (± стандартное отклонение) составили: группа I: 1650,5 ± 180,2 N; группа II: 615,8 ± 95,4 N; группа III: 950,3 ± 110,7 N; группа IV: 1425,6 ± 155,1 N. Анализ ANOVA выявил значимые различия между группами (p < 0,001). Все группы, кроме интактной, имели существенно меньшую прочность. Группа IV (ETT+PC+C) показала значительно более высокую сопротивляемость к разрушению по сравнению с группами II (ETT) и III (ETT+PC) (p < 0,05). Группа III также была прочнее группы II (p < 0,05). Несмотря на это, прочность группы IV оставалась заметно ниже интактной контрольной группы (p < 0,05).

ВЫВОДЫ. Для премоляров снижение прочности на разрушение происходит преимущественно вследствие подготовки эндодонтического доступа. Установка коронки полной облицовки обеспечивает значительное укрепление структуры зуба, тогда как добавление штифта и накопителя дает лишь небольшое повышение прочности. Полное восстановление прочности исходного интактного зуба современными реставрационными методами не достигается.

Ключевые слова: эндодонтическое лечение, протезное восстановление, штифт-накопитель, прочность на разрушение, лабораторное исследование, биомеханика

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INTRODUCTION

The main objective of contemporary dental care is to maintain the integrity of the patient's natural teeth. In recent years, endodontic therapy has emerged as a reliable and effective alternative to tooth extraction for patients suffering from pulpal or periapical disease [1]. Endodontically treated teeth (ETTs) rely on root canal treatment quality and, more importantly, prosthodontic restoration for long-term success [2]. It is often believed that ETT are more fragile and prone to breaking than important teeth. The severe loss of tooth structure resulting from caries, prior restorations, and the endodontic access cavity preparation itself is the primary cause of this elevated fracture risk, which is caused by several factors [3; 4].

When an endodontic access cavity is prepared, it breaks the tooth's structural continuity, which weakens the remaining coronal structure since the pulpal roof and marginal ridges no longer form an integrated “truss” [5]. On its own, access preparation may lessen tooth stiffness by around 5%, whereas occlusal isthmus preparation can lower it by 20-63%, according to studies [6]. It is currently known that the loss of structural integrity is the primary source of weakening [7], while changes in dentin physical qualities, such as dehydration and collagen cross-linking modifications after pulpectomy, have also been suggested as significant causes.

A variety of prosthodontic techniques are used to address this compromised structure. To keep the final restoration in place when there isn’t enough coronal tooth structure, a post-and-core is often used [8]. The purpose of a post is not to strengthen the tooth root but rather to secure the fundamental foundation. Actually, the radicular structure may be much more compromised after space preparation [9]. A full-coverage crown is the last piece of dental restoration equipment. Its purpose is to encase the residual tooth structure, preventing it from being damaged by functional occlusal stresses. This process is called the “ferrule effect” and has been shown to prevent teeth from breaking [10; 11].

Despite a general consensus on the need for restoration, the precise, incremental contribution of each restorative step to the overall fracture resistance remains a subject of investigation. While numerous studies have compared different post systems or crown materials [12; 13], few have systematically evaluated the stepwise progression from a non-restored ETT to a fully crowned tooth within a single experimental design. This creates a research gap in quantifying the exact benefit conferred by a post-and-core alone versus the combined effect of a post-and-core and a crown. Understanding this progression is crucial for clinicians to make evidence-based decisions, especially in situations where cost or treatment time might lead to compromises in the restorative plan.

Thus, this in-vitro study set out to measure and compare the fracture resistance of four different groups of endodontically treated human premolars at various points in their rehabilitation: (I) teeth that were left untreated, (II) teeth that had endodontic treatment but had no coronal restoration, (III) teeth that had endodontic treatment but had a fiber post-and-core restoration, and (IV) teeth that had endodontic treatment but had a post-and-core restoration plus a full-coverage crown. The groups under examination were hypothesized to have similar levels of fracture resistance (the null hypothesis).

AIM

Does the type of prosthodontic rehabilitation (post-and-core alone vs. post-and-core with a full-coverage crown) affect the fracture resistance of endodontically treated maxillary premolars?

1. To evaluate and compare the mean fracture resistance values of endodontically treated maxillary premolars restored with post-and-core alone vs. post-and-core with a full-coverage crown.

2. To assess the fracture patterns (favorable vs. unfavorable) in both groups and determine the clinical implications of the findings.

MATERIALS AND METHODS

Study design and sample selection

for orthodontic purposes, forty healthy, non-caries maxillary premolars were taken from a patient and placed in a 0.1% thymol solution. The teeth were measured buccolingually and mesiodistally to ensure consistency. One root, full development of the root tip, no visible signs of fractures or fissures (checked at 10x magnification), and the lack of any previous endodontic or restoration work were all requirements for admission. Excluded from consideration were teeth exhibiting abnormal root morphology, canals that had calcified, or substantial attrition. The chosen teeth were scaled using an ultrasonic instrument to remove calculus and soft tissue debris.

Sample Grouping

The 40 teeth were randomly assigned to four experimental groups ($n = 10$ each) using a simple lottery method:

Group I (Control): Intact teeth. No preparation or treatment was performed.

Group II (ETT): Endodontically treated teeth. A standardized endodontic access cavity was prepared, but no coronal restoration was placed.

Group III (ETT+PC): Fiber posts and composite cores for teeth that have undergone endodontic treatment.

Group IV (ETT+PC+C): Fiber posts, composite cores, and full-coverage cast metal crowns repair teeth that have undergone endodontic treatment.

Endodontic treatment protocol (Groups II, III, IV)

Using a high-speed handpiece with ample water spray, a standardized conservative occlusal access cavity was made for all teeth in Groups II, III, and IV using a #4 round diamond bur and a #245 carbide bur. Using a #15 K-file, the working length was set 1 mm below the radiographic apex. With a master apical file size of F3, the crown-down approach was used to prepare the canals using ProTaper Gold rotary nickel-titanium files (Dentsply Sirona, USA). A 2 mL solution of 5.25% sodium hypochlorite (NaOCl) was introduced into the canals between each file as part of the instrumentation process.

Five milliliters of 17% ethylenediaminetetraacetic acid (EDTA), five milliliters of 5.25% sodium hydroxide, and a last rinse with saline made up the last irrigation sequence. As part of the heated vertical compaction procedure, the canals were dried using sterile paper points and then sealed with gutta-percha points (Dentsply Sirona, USA) and AH Plus resin sealer (Dentsply Sirona, Germany). To mimic a tooth that is waiting for its ultimate restoration, the access cavities in Group II were intentionally left accessible.

Prosthodontic rehabilitation protocol (Groups III, IV)

To prepare the post space for teeth in Groups III and IV, a Largo Peeso reamer and the appropriate drill were used, ensuring that 4–5 mm of the apical gutta-percha remained intact. A 1.6 mm diameter fibre post (RelyX Fiber Post, 3M ESPE, USA) was used.

To prepare the post area for bonding, 37% phosphoric acid was etched into it, washed, and dried. Then, 3M ESPE, USA's Scotchbond Universal was applied, and it was light-cured. Using a self-adhesive resin cement (RelyX Unicem 2, 3M ESPE, USA), the fiber post was luted. The post was encased in a nanohybrid composite resin (Filtek Z350 XT, 3M ESPE, USA) to form a composite core, which was light-cured every 2 millimeters. A conventional crown preparation was the model for the core's form.

In Group IV, crowns were prepared for the teeth that had post-and-cores. The minimal height of the ferrule was maintained at 2.0 mm by preparing a 1.5 mm supragingivally circumferential chamfer border, 1.5 mm axial reduction, and 2.0 mm occlusal reduction. Cast cobalt-chromium alloy full-coverage crowns were manufactured after polyvinyl siloxane impressions. Crowns were set in place using glass ionomer cement (GC Fuji I, GC Corporation, Japan) while subjected to a steady 5 kg load for a duration of 10 minutes.

Specimen mounting and fracture testing

In blocks of auto-polymerizing acrylic resin, each of the forty specimens was set. To create an imprint of the periodontal ligament (PDL), a thin coating of light-body polyvinyl siloxane (0.2–0.3 mm) was applied to the tooth roots. These were then immersed in acrylic resin up to 2 mm below the cementoenamel junction (CEJ).

With the help of a universal testing machine (Instron Model 3369, USA), the specimens that were mounted were compressed. Applying the force vertically onto the central fossa of the occlusal surface, parallel to the long axis of the tooth, a steel ball with a diameter of 5 mm was used. If the load-deflection curve on the machine's software shows a severe drop, then catastrophic fracture has occurred, and the load was applied at a crosshead speed of 1 mm/min. We measured the maximal force in Newtons (N) that was applied at the fracture site. After the testing was finished, we looked at each specimen visually to see whether the fracture was favorable (repairable) or unfavorable (non-repairable).

Statistical analysis

Data on fracture loads were input into SPSS (Version 26.0, IBM Corp., USA) after collection. Each category has its own set of descriptive statistics computed, including means and standard deviations. The data was found to be normally distributed by using the Shapiro-Wilk test. In order to compare the average fracture resistance of the four groups, a one-way analysis of variance (ANOVA) was used. When comparing the groups in pairs, Tukey's honestly significant difference (HSD) post hoc test was used. A significance criterion of $p < 0.05$ was established.

RESULTS

All specimens had their fracture resistance values recorded and evaluated in Newtons. Table 1 shows the average, S.D., minimum, and maximum values for every category.

Group I (Intact) exhibited the highest mean fracture resistance (1650.5 ± 180.2 N), while Group II (ETT) showed the lowest (615.8 ± 95.4 N). The prosthodontically restored groups, Group III (ETT + PC) and Group IV (ETT + PC + C), demonstrated intermediate values of 950.3 ± 110.7 N and 1425.6 ± 155.1 N, respectively.

An F-test with a significance level of 115.6 and a p-value less than 0.001 showed that there was a statistically significant variation in the average fracture resistance between the four groups.

For pairwise comparisons, we used Tukey's HSD post hoc test; Table 2 summarizes the findings. All other groups were considerably weaker compared to the intact group (Group I) ($p < 0.001$ for all comparisons). In comparison to Group II (ETT) and Group III (ETT + PC), Group IV (ETT + PC + C) exhibited much greater fracture resistance ($p < 0.001$ for both). In a similar vein, Group III (ETT + PC) outperformed Group II (ETT) by a substantial margin ($p < 0.001$). Even though Group IV had a lot of reinforcing, their mean fracture resistance was still lower than the undamaged control group's ($p = 0.035$).

Table 1. Descriptive statistics of fracture resistance (N) for all groups

Таблица 1. Дескриптивная статистика прочности на разрушение (N) для всех групп

Group	N	Mean (N)	Standard Deviation (SD)	Minimum (N)	Maximum (N)
Group I (Intact)	10	1650.5	180.2	1410.2	1925.7
Group II (ETT)	10	615.8	95.4	480.5	750.1
Group III (ETT + PC)	10	950.3	110.7	785.4	1120.3
Group IV (ETT + PC + C)	10	1425.6	155.1	1205.8	1680.9

Table 2. Pairwise comparison of mean fracture resistance using Tukey's HSD test

Таблица 2. Парное сравнение средней прочности на разрушение с использованием критерия Тьюки (Tukey's HSD)

Comparison	Mean Difference (N)	Std. Error	p-value	Significance
Group I vs. Group II	1034.7	62.4	< 0.001	Significant
Group I vs. Group III	700.2	62.4	< 0.001	Significant
Group I vs. Group IV	224.9	62.4	0.035	Significant
Group II vs. Group III	−334.5	62.4	< 0.001	Significant
Group II vs. Group IV	−809.8	62.4	< 0.001	Significant
Group III vs. Group IV	−475.3	62.4	< 0.001	Significant

Table 3. Distribution of fracture modes in different groups

Таблица 3. Распределение типов разрушения в различных группах

Group	Favorable (Repairable) Fractures	Unfavorable (Non-repairable) Fractures
Group I (Intact)	8 (80%)	2 (20%)
Group II (ETT)	1 (10%)	9 (90%)
Group III (ETT+PC)	3 (30%)	7 (70%)
Group IV (ETT+PC+C)	7 (70%)	3 (30%)

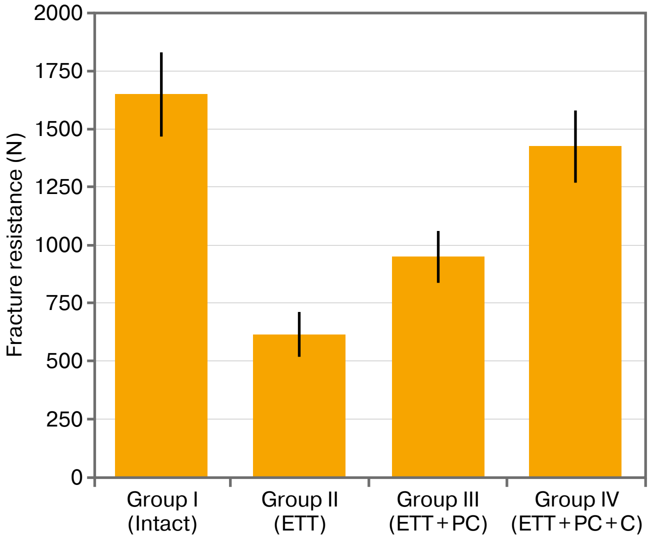

Fig. 1. Mean Fracture resistance

Рис. 1. Средняя прочность на разрушение

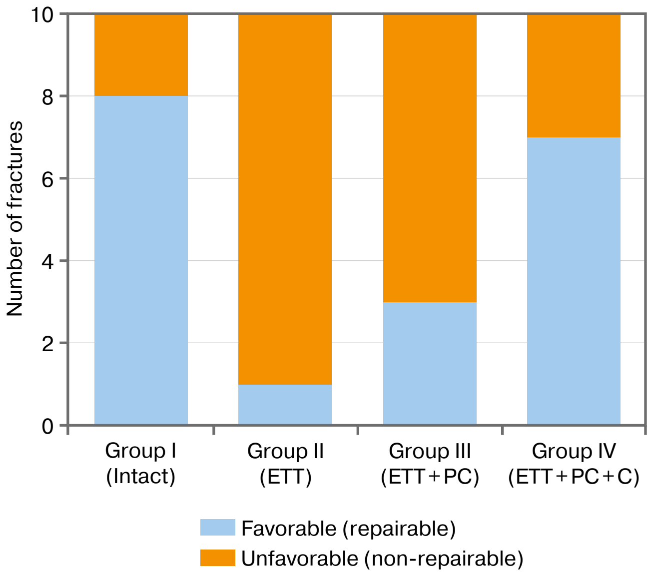

Fig. 2. Fracture modes

Рис. 2. Типы разрушения

Analysis of fracture modes revealed distinct patterns across the groups (Table 3). A fracture was deemed “favorable” if it was repairable (i.e., coronal to the simulated alveolar crest) and “unfavorable” if it was non-repairable (i.e., a vertical root fracture or a deep oblique fracture extending subcrestally). In the intact group, most fractures were oblique and located coronally. In contrast, Group II and Group III exhibited a higher percentage of catastrophic, unfavorable fractures. Group IV, with full-coverage crowns, showed a higher incidence of favorable fractures compared to the other ETT groups (Fig. 1, 2).

DISCUSSION

Maxillary premolar fracture resistance is significantly affected by endodontic treatment and the prosthodontic restoration option, according to this in-vitro investigation. We found a substantial difference between the groups, rejecting the null hypothesis that there would be none. The results demonstrate that strength decreases step-by-step from untreated teeth to teeth treated with endodontics, and then increases step-by-step when a post-and-core and full-coverage crown are added.

The highest fracture resistance observed in the intact teeth (Group I) is an expected finding and serves as a crucial benchmark. The structural integrity of a sound tooth, with its intact marginal ridges and dentinal arch, allows for the effective distribution of occlusal loads throughout the crown and root [5; 14]. The significant reduction in fracture resistance in Group II (ETT), which was approximately 37% of the intact group’s strength, underscores the detrimental effect of endodontic access preparation. This aligns with the seminal work by Reeh et al., who concluded that it is the loss of tooth structure, rather than changes in dentin properties, that is the primary contributor to the increased fracture susceptibility of ETT [6]. Our results confirm that merely performing endodontic treatment and leaving the tooth unrestored renders it critically weak and prone to catastrophic failure.

Group III, which included a fiber post and composite core, showed a considerable improvement in fracture resistance when compared to Group II, which did not receive any restoration to the ETT. This enhancement is because the post-and-core method not only restores the missing tooth structure but also provides a strong foundation, therefore distributing some of the occlusal stress [15]. Fiber posts may lessen the likelihood of root fracture compared to stiff metal supports since their elastic modulus is comparable to that of dentin [16]. It is clear that a post-and-core alone is unable to protect the tooth from fracture, as Group III’s strength was just about 58% of the entire group. Unsupported cusps are nevertheless susceptible to splitting under stress, as shown by the high incidence of unfavourable fractures in this group (70%).

Group IV, which received a full-coverage crown on top of the post-and-core, showed the greatest improvement in fracture resistance, which is the most important conclusion of the research. In comparison to the intact control group, this one had a mean fracture strength that was over 86% higher. The “ferrule effect” that the crown provides is mostly responsible for this remarkable enhancement [10; 17]. Crown preparation on stable tooth structure apical to the core uses a 360-degree collar to brace the tooth, which protects the cusps from occlusal stresses that may cause them to bend or fracture. The compromised coronal structure is shielded from further stress by this action, which moves it to the crown and along the root’s long axis [11]. Since the ferrule probably limited the fracture and prevented it from propagating deep into the root, the better fracture mode in Group IV (with 70% of fractures being favorable, or repairable) further supports the protective function of the crown [18].

Importantly, even with this substantial reinforcement, Group IV’s fracture resistance was statistically lower than Group I’s, which had entire teeth. This suggests that restorative ETTs still can’t match the biomechanical performance of healthy teeth, no matter how sophisticated the materials or methods used. Because of the intrinsic loss of a monolithic structure and the existence of various interfaces, such as dentin-cement-post, dentin-core, and dentin-crown, potential planes of weakness are created, which do not exist in an intact tooth [19].

It is important to recognize the study’s limitations. This study has limitations as an in-vitro experiment since it does not account for the complex oral environment with its ever-changing, multi-directional stresses, temperature cycling, and the impact of the viscoelastic characteristics of the periodontal ligament. The use of a static, vertical load represents a simplified stress model compared to the cyclic and eccentric forces experienced during mastication. The study was also limited to a single tooth type (maxillary premolars), and results may differ for anterior or molar teeth with different anatomical and loading characteristics. Future research should incorporate cyclic loading to simulate fatigue and evaluate different restorative materials, such as ceramic crowns and various post systems.

Nonetheless, the clinical implications of these findings are clear. Endodontic treatment alone severely compromises a tooth’s structural integrity. Leaving an ETT without a definitive coronal restoration, even for a short period, places it at high risk of fracture. While a post-and-core is essential for retaining the final restoration when coronal structure is lacking, it offers only moderate reinforcement. The placement of a full-coverage restoration that provides a ferrule effect is paramount for the long-term survival of endodontically treated posterior teeth, as it significantly enhances their fracture resistance and promotes more favorable fracture patterns if failure does occur.

CONCLUSIONS

Within the limitations of this in-vitro study, the following conclusions were drawn:

1. When compared to teeth that are not prepared for endodontic access, maxillary premolars’ fracture resistance is drastically reduced.
2. The addition of a composite core and fiber post to an endodontically treated tooth increases its fracture strength compared to an untreated tooth by a modest but statistically significant margin.
3. For maximum reinforcement, prosthodontic rehabilitation using a post-and-core in conjunction with a full-coverage crown is the way to go. This method brings the tooth’s fracture resistance up to par with that of natural teeth.
4. A completely capped tooth that has had endodontic treatment has a much less fracture strength than an untreated, healthy tooth, even after the best restoration possible.

In order to guarantee the structural integrity and clinical life of teeth that have had endodontic treatment, our data highlight the vital need of prosthodontic rehabilitation, namely complete cuspal covering, which must be done promptly and appropriately.

REFERENCES / СПИСОК ЛИТЕРАТУРЫ

1. Ng Y.L., Mann V., Rahbaran S., Lewsey J., Gulabivala K. Outcome of primary root canal treatment: systematic review of the literature – part 1. Effects of study characteristics on probability of success. *Int Endod J*. 2007;40(12):921–939. https://doi.org/10.1111/j.1365-2591.2007.01322.x
2. Gillen B.M., Looney S.W., Gu L.S., Loushine B.A., Weller R.N., Loushine R.J. et al. Impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment: a systematic review and meta-analysis. *J Endod*. 2011;37(7):895–902. https://doi.org/10.1016/j.joen.2011.04.002
3. Dietschi D., Duc O., Krejci I., Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: a systematic review of the literature, Part II (Evaluation of fatigue behavior, interfaces, and in vivo studies). *Quintessence Int*. 2008;39(2):117–129.
4. Tang W., Wu Y., Smales R.J. Identifying and reducing risks for potential fractures in endodontically treated teeth. *J Endod*. 2010;36(4):609–617. https://doi.org/10.1016/j.joen.2009.12.002
5. Kishen A. Mechanisms and risk factors for fracture predilection in endodontically treated teeth. *Endod Topics*. 2006;13(1):57–83. https://doi.org/10.1111/j.1601-1546.2006.00201.x
6. Reeh E.S., Messer H.H., Douglas W.H. Reduction in tooth stiffness as a result of endodontic and restorative procedures. *J Endod*. 1989;15(11):512–516. https://doi.org/10.1016/S0099-2399(89)80191-8
7. Sedgley C.M., Messer H.H. Are endodontically treated teeth more brittle? *J Endod*. 1992;18(7):332–335. https://doi.org/10.1016/S0099-2399(06)80483-8
8. Cheung W. A review of the management of endodontically treated teeth. Post, core and the final restoration. *J Am Dent Assoc*. 2005;136(5):611–619. https://doi.org/10.14219/jada.archive.2005.0232
9. Schwartz R.S., Robbins J.W. Post placement and restoration of endodontically treated teeth: a literature review. *J Endod*. 2004;30(5):289–301. https://doi.org/10.1097/00004770-200405000-00001

10. Stankiewicz N., Wilson P. The ferrule effect. *Dent Update*. 2008;35(4):222–228. https://doi.org/10.12968/denu.2008.35.4.222
11. Juloski J., Radovic I., Goracci C., Vulicevic Z.R., Ferrari M. Ferrule effect: a literature review. *J Endod*. 2012;38(1):11–19. https://doi.org/10.1016/j.joen.2011.09.024
12. Salameh Z., Sorrentino R., Ounsi H.F., Goracci C., Tashkandi E., Tay F.R., Ferrari M. Effect of different all-ceramic crown system on fracture resistance and failure pattern of endodontically treated maxillary premolars restored with and without glass fiber posts. *J Endod*. 2007;33(7):848–851. https://doi.org/10.1016/j.joen.2007.01.017
13. Zicari F., Van Meerbeek B., Scotti R., Naert I. Effect of ferrule and post placement on fracture resistance of endodontically treated teeth after fatigue loading. *J Dent*. 2013;41(3):207–215. https://doi.org/10.1016/j.jdent.2012.10.004
14. Magne P. Efficient 3D finite element analysis of dental restorative procedures using micro-CT data. *Dent Mater*. 2007;23(5):539–548. https://doi.org/10.1016/j.dental.2006.03.013
15. Akkayan B., Gülmez T. Resistance to fracture of endodontically treated teeth restored with different post systems. *J Prosthet Dent*. 2002;87(4):431–437. https://doi.org/10.1067/mpr.2002.123227
16. D'Arcangelo C., Cinelli M., De Angelis F., D'Amario M. The effect of resin cement film thickness on the pullout strength of a fiber-reinforced post system. *J Prosthet Dent*. 2007;98(3):193–198. https://doi.org/10.1016/S0022-3913(07)60055-9
17. Pereira J.R., de Ornelas F., Conti P.C., do Valle A.L. Effect of a crown ferrule on the fracture resistance of endodontically treated teeth restored with prefabricated posts. *J Prosthet Dent*. 2006;95(1):50–54. https://doi.org/10.1016/j.prosdent.2005.10.019
18. Santos-Filho P.C., Veríssimo C., Soares P.V., Saltarelo R.C., Soares C.J., Marcondes Martins L.R. Influence of ferrule, post system, and length on biomechanical behavior of endodontically treated anterior teeth. *J Endod*. 2014;40(1):119–123. https://doi.org/10.1016/j.joen.2013.09.034
19. Soares C.J., Pizi E.C., Fonseca R.B., Martins L.R. Influence of root embedment material and periodontal ligament simulation on fracture resistance tests. *Braz Oral Res*. 2005;19(1):11–16. https://doi.org/10.1590/s1806-83242005000100003

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The author made a substantial contribution to the preparation of the manuscript, including the conception and design of the study, data collection, analysis and interpretation of data, critical revision of the article for important intellectual content, and final approval of the version to be published.

ВКЛАД АВТОРОВ

Автор внес существенный вклад в подготовку рукописи, включая разработку замысла и дизайна исследования, сбор, анализ и интерпретацию данных, критический пересмотр статьи с точки зрения значимого интеллектуального содержания и окончательное одобрение версии для публикации.