Caspian J of Dent Res

Original Article

Fracture strength of teeth restored with fiber post and apical plug

Zahra Sadat Madani[1],Azadeh Harandi [2], Ensie Geraily[3]✉,Ali Bijani[4],Samane Gharekhani[5]

1.Associate Professor, Dental Materials Research Center, Department of Endodontics,Faculty of Dentistry,Babol University of Medical Sciences, Babol, IR Iran.
2.Assistant Professor, Dental Materials Research Center ,Department of Endodontics, Faculty of Dentistry, Babol University of Medical Sciences, Babol, IR Iran.
3. Assistant Professor, Department of Endodontics, Faculty of Dentistry, Golestan University of Medical Sciences, Gorgan,IR Iran.
4. General Practitioner, Non Communicable Pediatric Diseases Research Center, Health Research Institute, Babol University of Medical Sciences, Babol, IR Iran.
5. Assistant Professor, Dental Materials Research Center ,Department of Pedodontics, Faculty of Dentistry, Babol University of Medical Sciences, Babol, IR Iran.

✉Corresponding Author: Ensie Geraily, Faculty of Dentistry, Golestan University of Medical Sciences, Gorgan, IR Iran.
Email: ensiegeraily@yahoo.com **Tel:** +989115696434

Received: 11 Apr 2017 Accepted: 3 Sept 2017

Abstract
Introduction: The aim of this study was to assess the fracture strength of immature single-rooted teeth restored with fiber post and apical plug.
Materials &Methods: In this experimental study, fifty mandibular premolars were divided into five groups. The coronal and apical portions were cut to obtain15±1 mm root lengths and cleaning &shaping were performed. Peeso reamer #4 was passed the apex by 1 mm to simulate an immature tooth and the apical portion in group 1 to 5 was filled by lateral compaction of 5 mm of gutta-percha; 5 mm of mineral trioxide aggregate (MTA); 5mm of calcium enriched mixture (CEM) cement; 3 mm of MTA and 2 mm of gutta-percha by vertical condensation and 3 mm of CEM cement and 2 mm of gutta-percha, respectively. The remaining portion was restored with glass fiber post and self-etch cement and composite cores were built. Compressive load was applied at a crosshead speed of 1 mm/minute at 90 ° angle until fracture in a universal testing machine. Data were analyzed using ANOVA in SPSS16.
Results: The mean±SD fracture strength was recorded 607.8±162.41 N, 700.48±183.24 N, 595.16±171.77 N, 886.36±382.92N, and 868.87±440.36 N in groups one to five, respectively. No significant difference was observed among the experimental groups (p=0.1).
Conclusion: In immature teeth requiring an apical plug, fiber post can be placed directly on the MTA and CEM apical plugs and there is no need for placing gutta-percha on the plug.
Keywords: Premolar, Root canal therapy, Tooth fractures

Citation for article: Madani ZS, Harandi Z, Geraily E, Bijani A, Gharekhani S. Fracture strength of teeth restored with fiber post and apical plug. Caspian J Dent Res 2017; 6: 15-22.

مقاومت به شکست دندان های درمان شده با فایبر پست و پلاگ اپیکالی

زهراسادات مدنی، آزاده هرندی، انسیه گرایلی*، علی بیژنی، سمانه قره خانی

چکیده

مقدمه: هدف این مطالعه بررسی مقاومت به شکست دندانهای نابالغ تک ریشه درمان شده با پست فایبر و پلاگ اپیکالی می باشد.

مواد و روش ها: در این مطالعه آزمایشگاهی، ۵۰دندان پرمولر مندیبل به ۵ گروه تقسیم شدند. قسمت ریشه ای و تاجی دندان هابرش داده شد تا طول ریشه ۱± ۱۵ میلیمتر حاصل شود و آماده سازی کانال ها انجام شد. پیزوریمر شماره ۴ به اندازه ۱ میلیمتر فراتر از اپکس جهت مشابه سازی با دندان نابالغ، وارد شد و پر کردن ناحیه اپیکال در گروههای ۱ تا۵ به ترتیب با تراکم جانبی ۵ میلیمتر گوتاپرکا؛ MTA به ضخامت ۵ میلیمتر ؛ CEM به ضخامت ۵ میلیمتر ؛ ۳میلیمتر MTA و ۲ میلیمتر گوتاپرکا به روش تراکم عمودی و ۳میلیمتر CEM و ۲ میلیمتر گوتاپرکا به روش تراکم عمودی انجام شد. باقیمانده ریشه با گلاس فایبر پست و سمان خود سخت شونده پر شد و کور کامپوزیتی ساخته شد. نیروی فشاری ورتیکالی روی سطح اکلوزال با سرعت 1min/mm با زاویه ۹۰ درجه به موازات محور طولی ریشه تا لحظه شکست توسط دستگاه یونیورسال وارد شد. داده ها توسط آزمون آماری ANOVAدر نرم افزار SPSS16 آنالیز شدند.

یافته ها: میانگین و انحراف معیار نیروی مقاومت شکست بترتیب۱۶۲/۴۱±۶۰۷/۸، ۱۸۳/۲۴±۷۰۰/۴۸، ۱۷۱/۷۷±۵۹۵/۱۶، ۳۸۲/۹۲±۸۸۶/۳۶و ۴۴۰/۳۶±۸۶۸/۸۷ نیوتن برای گروه های۱ تا۵ بود. اختلاف معنی داری بین گروه های آزمایشی مشاهده نشد. (p= 0.1).

نتیجه گیری: در دندان های نابالغ نیازمند پلاگ اپیکالی ، میتوان پست فایبر را بطور مستقیم برروی پلاگ اپیکالی قرار داد و نیاز به قراردادن گوتاپرکا بر روی پلاگ اپیکالی MTA&CEM نیست.

واژگان کلیدی: پرمولر ، درمان کانال ریشه، شکستگی دندان

[DOR: 20.1001.1.22519890.2017.6.2.5.8]

[DOI: 10.22088/cjdr.6.2.15]

Introduction

The most important step in root canal treatment is appropriate filling of the root canal system to obtain an appropriate apical seal. [1] In some cases such as immature teeth with pulp necrosis and/or external root resorption, and in cases where instruments are used beyond the apex, achieving to an appropriate apical seal was very challenging. [2]In the past, apexification with calcium hydroxide was the most common treatment for these cases but various studies showed that the teeth treated with calcium hydroxide were more prone to fracture due to the long-term therapeutic process. [3-6] However, the best alternative for apexification with calcium hydroxide is to use an apical barrier. The mineral trioxide aggregate (MTA) and calcium enriched mixture (CEM) cement are suitable material for creating an apical barrier with a one-session apexification treatment. [7] MTA contains tricalcium oxide, tricalcium silicate and silicon oxide. Optimal biocompatibility, osteogenic potential, cementogenic potential and high sealing ability are among the favorable properties of MTA. [7-9] The CEM cement was recently introduced as a new biomaterial. [10] This cement mainly consists of CaO, SO_3, P_2O_5 and SiO_2. This cemen-treleases calcium hydroxide during setting. [10] Its antibacterial property is similar to that of calcium. hydroxide and higher than that of MTA.[11] Also, CEM cement like MTA has low cytotoxicity[12] and it has also shown favorable results in vital pulp therapy such as pulpotomy of permanent teeth, and repair of perforations and internal/external root resorptions. [13]

Risk of fracture of endodontically-treated teeth remains a problem in dentistry. It is mainly due to the loss of moisture, degradation of dentinal collagen, decreased elasticity and weakening of tooth structure during preparation. [14] In teeth with impaired root development or short root length, the risk of fracture of teeth is higher. [15] Therefore, in immature teeth, the tooth structure should be reinforced to ensure long-term clinical service. To restore immature teeth with severely damaged crowns, different materials such as composites, resin modified glass ionomer cements and fiber posts are used to strengthen the tooth structure. Several studies have suggested that fiber posts, because of having a flexural strength similar to that of dentin, increase the fracture strength of immature roots and reduce the risk of their catastrophic fracture. [16,17] Dikbas et al.[15]compared different methods for restoration of teeth with quartz fiber posts, as retro-fill after placing 3-4 mm of MTA as an apical plug and showed that fiber posts significantly increased the fracture strength of root.

Many studies have suggested that the fracture strength of teeth with posts depends not only on the type of post[18, 19], but also on factors such as the amount of remaining tooth structure[20], as well as the diameter, modulus of elasticity[21] and length of the post. [22] Researchers stated that the length of posts is related to root fracture and declared that the length of a post should be two-thirds of the length of the root, or at least the same as the length of the clinical crown[22-24] or at least exceed half of the root length.[25] However, the root length may be limited for restoration of immature teeth with an intracanal post. Therefore, placing the gutta-percha on the apical plug and beneath the post would further reduce the available space for the post or may force the clinician to decrease the thickness of plug, which would compromise the seal. In such cases, direct placement of the post on the apical plug would be inevitable.

Yildirim et al. [26] stated that in teeth requiring post and core restoration, MTA can be used in the root canals as the filling material for the apical plug. Considering the studies on the apical seal, questions may be raised regarding the effect of placing a post directly on top of the apical plug on the fracture strength of teeth restored with posts. No studies have been performed on fracture strength when fiber post is directly placed on MTA and CEM apical plug or when gutta-percha is used. This study sought to assess the fracture strength of teeth restored with fiber posts placed directly on top of the apical plug in comparison with the placement of gutta-percha beneath the post.

Materials & Methods

This laboratory study was conducted on single-rooted mandibular premolar teeth freshly extracted due to orthodontic reasons, periodontal disease and severe caries. The teeth were immersed in saline followed by 5.25% sodium hypochlorite for disinfection for 20 minutes. Soft tissue residues, debris and calculus were removed from the tooth surfaces using Gracey curettes # 3 and 4. The teeth were also inspected under a stereomicroscope at ×10 magnification to ensure the absence of cracks. The teeth with resorption, cracks, hypoplasia, root caries and anatomical abnormalities were excluded. Finally, 50 teeth were selected for the study using consecutive sampling. The lengths of the roots were standardized at 15±1 mm by cutting the coronal 2 mm above the cement–enamel junction) and apical portions. After removal of the pulp tissue, the samples were immersed in saline at 37°C until the experiment to prevent dehydration. The working length was determined 0.05-1 mm shorter than the apex using a K-file #15.

The Protaper rotary system (DentsplyMaillefer, Ballaigues, Switzerland) with the sequence of SX, S1, S2, F1, and F2 was used for root canal shaping. The root canals were irrigated using 2 mL of saline during the cleaning process. To simulate teeth with immature apices, Peeso reamers #1-4 were introduced to the root canals, and a #4 Peeso reamer passed through the apex by one millimeter. Finally, saline was used for final flush. The canal space was dried using paper points (Diadent, Diadent Group, International, and Burnaby, BC, Canada) and the samples were divided into five groups as follows:

Group I: Gutta-percha (Gapadent Co, Ltd) and AH26 sealer (AH-26, DentsplyDetrey GmbH, Konstanz, Germany) were applied using cold lateral compaction method. A master cone was reached to the working length and was radiographically confirmed. Next, AH $_{26}$ sealer was prepared according to the manufacturer's instructions. Then, the root canals were filled using a proper size spreader (DentsplyMaillefer, Ballaigues, Switzerland) and accessory gutta-percha cones by cold lateral compaction. The gutta-percha cones were cut 1 mm below the reference point. Finally, Cavit (Cavisol, Golchai, IRI) was placed on the orifices for temporary restoration of the access cavity.

Group II: In this group, MTA plug with 5 mm thickness was placed as the apical plug. White ProRoot MTA (Angelus, Londrina, Brazil) was prepared according to the manufacturer's instructions and transferred into the canal space using an amalgam carrier. It was incrementally applied and condensed by an endodontic plugger (DentsplyMaillefer, Ballaigues, Switzerland) to achieve a 5 mm thick apical plug.

Finally, the length of MTA was radiographically confirmed. A wet cotton pellet was placed over the MTA and the access cavity was temporarily restored with Cavite. The samples were stored at 37°C and 100% humidity for 24 hours to allow complete setting of MTA.

Group III: In this group, a CEM cement apical plug with 5mm thickness was placed. The CEM cement (Bionique Dent, Tehran, Iran) was prepared according to the manufacturer's instructions and incrementally applied to the canal space using an amalgam carrier. It was well condensed by endodontic pluggers to achieve a 5 mm thick apical plug. After confirming the thickness of CEM cement apical plug radio graphically, a wet cotton pellet was placed in the remaining canal space. The access cavity was temporarily restored with Cavite. The samples were stored at 37°C and 100% humidity for 24 hours to allow complete setting of MTA.

Group IV: In this group, a MTA plug with 3 mm thickness was placed and 2 mm of gutta-percha was placed over it. White ProRoot MTA (Angelus, Londrina, Brazil) was applied as explained for group II to achieve 3 mm thickness of apical plug. Its length was radiographically confirmed, a wet cotton pellet was placed over it and the samples were incubated as in group II. After 24 hours, 2mm of gutta-percha were placed on the apical plug using the vertical condensation technique. The samples were incubated at 37°C for one week.

Group V: In this group, CEM cement with 3mm thickness was placed as the apical plug and 2 mm of gutta-percha was placed over it. The CEM cement was applied as in group III to achieve 3mm thickness. After 24 hours of incubation as explained in group III, 2mm of gutta-percha was applied as in group IV. The samples were incubated at 37°C for one week.

Post space preparation: The samples were mounted in PVC rings with 3 cm diameter and 2 cm height containing self-cure acrylic resin (Cold cure acryl, Marlic medical Industries Co, Tehran, Iran) perpendicular to the horizontal plane of the surveyor (Surveyor, Saeshin Precision Ind Co, Ltd, korea). The surface of the acrylic resin had 2mm distance from the cementoenamel junction to the CEJ. For post space preparation in the first group, 10mm of gutta-percha were removed from the root canal by ≠ 2, 3 and4low-speed Peeso reamer (Mani, Japan). Post space was prepared using #1 drill (Finishing Drill, DTLigh post, RTD, France) with 1.5mm diameter for placement of the fiber posts(DTLigh post, RTD, France).

Fiber post cementation: Paper points were used to dry the root canals. Etching was done with 38% phosphoric acid (PULPDENT CORPORATION, Watertown, MA02471-0780, and USA) for 15 seconds, before post cementation. After washing and drying, fiber posts were cemented using Panavia resin cement (Panavia F2.o, Kuraray Medical Inc., Osaka, Japan). The A and B primers (Alloy Primer; Kuraray Co Ltd) were mixed with equal volume according to the manufacturer's instructions and applied to the canal using a micro brush. It was also applied to the coronal dentin. After 30 seconds, ED Primer II was dried using mild air spray and the excess material was removed with a paper point. Afterwards, the A and B cements were mixed in equal amounts and applied to the post. The post was then placed in the canal to the desired length, and light curing was performed for 40 seconds (Coltulux 75, Coltene/Whaledent Inc., OH, USA). After cementation, fiber posts were cut at 4 mm height above the root canal orifice using a disc.

Excite (Ivoclar Vivadent) was applied to the coronal dentin and fiber post for 15 seconds, and after 20 seconds of light curing, a transparent prefabricated crown was filled with composite (Clearfill Photo Core, Kururay Medical Inc., Japan.) and placed over the remaining part of the post. The composite cores were light cured by a light curing unit from the mesial, distal, buccal and lingual for 40 seconds, and next, the transparent prefabricated crown was separated from the core. Finally, the samples were placed in a universal testing machine (ZwickRoell 020, Ulm, Germany) as seen in Fig. 1. The load was applied parallel to the longitudinal axis of the tooth at a crosshead speed of 1 mm per minute by a round piston (1 mm diameter) until failure occurred.

The load at facture was recorded in Newton, and reported as the fracture strength of the sample. The results were analyzed using SPSS 16, and one-way ANOVA.

Results

The Mean±SD fracture strength was recorded 607.8±162.41, 700.48±183.24, 595.16±171.77, 886.36±382.92, and 868.87±440.36N in groups one to five, respectively. According to ANOVA, no significant

[DOR: 20.1001.1.22519890.2017.6.2.5.8]
[DOI: 10.22088/cjdr.6.2.15]

difference was observed among the experimental groups (P=0.1).

In addition, no significant difference was found according to Tukey's post hoc and Kruskal Wallis tests, and only the fourth group, (MTA apical plug, with the length of 3 mm, and 2 mm of gutta-percha on apical plug) showed slightly, but not significantly, higher fracture strength.

Discussion

The purpose of this study was to evaluate the fracture strength of teeth restored with fiber post placed on the apical plugs of MTA and CEM cement with or without gutta-percha on the apical plug. No significant difference was observed in the fracture strength of teeth restored with fiber post placed on the apical plug in the presence and absence of gutta-percha.

Immature teeth are prone to fracture due to trauma and mastication forces. [26] Fracture of immature teeth with incompletely formed dentinal walls/roots is a major concern after endodontic and restorative procedures. In order to reinforce the roots in open apex teeth, an apical barrier is necessary for an appropriate seal. One-stage apexification treatment with MTA is often successful. [24] The advantages of using MTA include shorter treatment period, an appropriate apical seal and inducing hard tissue formation when it is used as an apical barrier. [27]

Various studies have been conducted using MTA as an apical plug with different thicknesses. [28, 29] Martin et al.[28] showed that 3-5 mm thickness of orthograde MTA apical plug in one-step apexification provided an acceptable seal. Although complete orthograde filling of the root with MTA yielded superior initial seal compared to a 3-5 mm-thick MTA plug, the two experimental groups were similar in their fracture strength, and there was no certain benefit in increasing the thickness of MTA apical plug for root strengthening in apexification.

The current study compared the fracture strength of immature teeth restored with fiber posts, with 3 mm and 5 mm thickness of MTA apical plug, and 3 mm and 5 mm thickness of CEM cement apical plug using universal testing machine. The results showed that there was no significant difference in the fracture strength of teeth with MTA apical plug with 3 and 5mm thickness, and 3 and 5mm thickness of CEM cement apical plug. These findings were similar to those of Milani et al. [29] According to the results of Milani et al, [29] no difference was observed in fracture strength of 5mm MTA and 5mm CEM apical plugs in comparison with complete filling of the canal with MTA. The current results indicated the successful use of MTA and CEM cement apical plugs in terms of fracture strength; thus, they can be used in teeth with short roots where the limited length of the root would not allow placement of gutta-percha beneath the post. Results of the present study suggested slightly, but not significantly, higher fracture strength in groups with MTA apical plug and CEM cement apical plug compared to the apical plug of gutta-percha, regardless of thickness. A previous study using finite element analysis [30] revealed that materials with an elastic modulus similar to that of dentin could strengthen the weak roots, which justifies the failure of gutta-percha and Resilon in strengthening the tooth structure. [31]

The elastic modulus of MTA is not known, but the elastic modulus of Portland cement is about 1.7 GPa, which increases to 30-15 GPa after setting[32] and it is approximately similar to the elastic modulus of dentin with14-18.6 GPa. In this study, after placing the apical plug, glass fiber prefabricated post with composite core was used to restore and reinforce the tooth structure. The fracture strength of teeth can be enhanced using various materials and techniques such as composite resin, glass ionomer reinforced cement, resin root canal filling materials (Resilon) and various post systems. [33] Intracanal posts may be good options to prolong the clinical service of compromised teeth. [33] Among the available types of posts and cores, cast metal post and core, prefabricated metal posts with amalgam or composite core, and fiber posts with composite cores are most commonly used. Despite the popularity of cast post and core systems, a cast post and core has some disadvantages, which may affect the long-term success of restoration, including uneven stress distribution, biological side effects due to the microleakage and corrosion, and color reflection of the cast post and core on all-ceramic restorations .[34]

Nowadays, prefabricated post systems, such as resin posts reinforced with fibers, are most commonly used for restoration of severely damaged teeth because of an elastic modulus similar to that of dentin, biocompatibility and excellent esthetics for tooth-colored restorations use. [35]

Dikbas et al,[15]and Schmoldt et al.[36] evaluated the effect of fiber posts on the fracture strength of immature

[DOR: 20.1001.1.22519890.2017.6.2.5.8]

[DOI: 10.22088/cjdr.6.2.15]

teeth. According to the obtained results, quartz fiber and glass fiber posts increased the strength of teeth with a significant difference compared to zirconia, titanium and metal Brito-Júnior et al.,[37] in 2014 evaluated the effect of adhesive restorations on fracture strength and stress distribution in teeth with immature apex and apical plug.The results indicated that the highest fracture strength was related to the groups of fiber posts alone and fiber posts relined with composite and the lowest one was associated with the gutta-percha group. According to the previously reported successful results of the application of fiber reinforced post system for the restoration of immature teeth, the fiber post system with composite core was used in the current study.

In addition to the type of post, other factors related to the post, such as the length of post affect the fracture strength. In open apex teeth, owing to external apical resorption, trauma and necrosis and/or perforation apical plug are often required for an apical seal; however, limits with regard to root length often exist. Due to these limitations, the post may be placed directly on the apical plug in order not to compromise the post length. In this regard, Yildirim et al,[26] in their study used MTA as an apical plug with a length of 5 mm beneath the post. They prepared the post space at two different times (immediately and after a one-month delay).

The results showed that post space preparation at two different times did not affect the integrity of apical plug seal with a thickness of 5 mm. Several studies have evaluated the apical seal using MTA and CEM cement apical plug with posts placed directly on the plugs, but no studies have compared the fracture strength of teeth restored with direct placement of posts on apical plugs in the presence and absence of gutta-percha on the plug. Considering the lack of studies in this field, this study aimed to assess the fracture strength of teeth with direct placement of post on the apical plug in the presence and absence of gutta-percha. According to the results of the current study, no significant difference was observed between the groups with different thicknesses of MTA and CEM, by direct placing of the post on the plug in absence of gutta-percha (groups 2 and 3) and presence of gutta-percha on the plug (groups 4 and 5).Although in the groups that gutta-percha with a thickness of 2 mm was placed on the apical plug with a thickness of 3 mm, a greater force (but not significantly) was required for fracture. Therefore, it may be concluded that due to its flexibility, gutta-percha absorbs the sock, and less force is transferred to the root structure. In the current study, the samples were restored with composite cores and fiber posts without a prosthetic crown. Thus, factors related to a prosthetic crown and their effects on fracture strength were not present. The current study was similar to those of Dikbas et al,[15] and Dilmener et al.[33] who sought which assessed the fracture strength of immature teeth with different post systems. They stated that, by omitting factors related to the use of a prosthetic crown, structural integrity and fracture strength of teeth can be better assessed in detail.

This study, similar to that of Schmoldt et al, [36]and Dikbas et al.[15] did not mount the teeth directly in acrylic resin. The roots were covered with silicon to simulate the periodontal ligament and movements of roots during load application although covering the roots with silicon or wax before mounting in acrylic resin may not exactly simulate clinical conditions and position of the tooth in bone. Stuart et al, [38] in 2006 and Wilkinson et al, [31] in 2007 found no statistically significant difference in the mean fracture strength of roots covered before mounting by materials such as polyether and self-cured rubber compared to those not covered. The result of the present study represented that the fracture strength of immature teeth, restored with MTA apical plug and CEM apical plug, did not demonstrate a significant difference by placing the post directly on the plug, or on gutta-percha.

This current study has some limitations such as the type of test used, that is, a single cycle to failure, and the difference between the oral environment and the laboratory environment; thus, the results of this study cannot not exactly reflect the clinical situation. In in vitro studies, the forces are exerted to the tooth, at one point by Instron testing machine, until the fracture occurs. Therefore, the mean forces applied by Instron testing machine, in this and other in vitro studies are considerably higher than the maximum physiological forces exerted to the tooth during mastication, in the wet environment of the oral cavity and under the influence of chemical and thermal changes. It can be stated that what causes the fracture of teeth and restorations in the oral environment is the fatigue due to the continuous forces with lower intensity.[35]

Future Further studies are required on the fracture strength of teeth with different apical plugs in presence/absence of gutta-percha and post and core systems with prosthetic crown to draw a definite conclusion on restoration of immature teeth and to evaluate the mode of failure using a scanning electron microscope.

Conclusion

Within the limitations of this study, it can be concluded that for restoration of immature teeth requiring apical plug with short roots, the fiber post can be directly placed on the MTA and CEM cement apical plug, and there is no need for placing gutta-percha on the plug.

Acknowledgments

The authors would like to thank all the administrative and secretarial staff of the Department of Endodontics of Dental Faculty of Babol University of Medical Sciences for their contribution to the maintenance of our patients' record without which this project would have been impossible.

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

Authors' Contributions

The study was designed by Zahra Sadate Madani and Azade Harandi. The study data were collected by Ensie Geraily. Analysis and interpretation of data were conducted by Ali Bijani and drafting of the manuscript, and critical revision of the manuscript for important intellectual content were performed by Ensie Geraily and Samane Gharekhani. Study supervision was conducted by Zahra Sadate Madani and Ensie geraily.

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