ORIGINAL RESEARCH

Static Loading of Different Intraradicular Preparation Depths of Trinia Endocrowns in Maxillary Canines

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Abstract

Aim: The aim of this study is to compare the fracture resistance of canine teeth restored using TRINIA Endocrowns with three different types of preparations (2, 3, and 4 intracanal preparations).

Materials and methods: Thirty maxillary-extracted canines were collected. All teeth were fixed in orthodontic acrylic resin and decapitated at the level of the proximal cemento-enamel junction (CEJ). After being endodontically treated, specimens were distributed equally between 3 groups ($n = 10$) with different preparation depths (GT: 2 mm Intraradicular Preparation, GH: 3 mm Intraradicular Preparation, GF: 4 mm Intraradicular Preparation). Thirty TRINIA endocrowns were dry milled. After surface treatment, all endocrowns were bonded to their corresponding roots using Permaflo a dual-cure resin cement. Each specimen was then fixed in the lower part of a universal testing machine with a load cell of 5 KN, at an angle of 45 degrees to the tooth long-axis at 0.5 mm/min crosshead speed. Failure loads were recorded in Newton's. Data were recorded, organized, and statistically investigated.

Results: Shapiro–Wilk tests revealed that the data were not normally distributed. Descriptive statistics revealed a high mean fracture resistance of GH (647 N), then GT (475.6 N), and finally GF (353.9 N). The Kruskal–Wallis test revealed a significant difference that existed between the groups being studied ($p = 0.036$).

Conclusion: TRINIA endocrowns with intracanal preparations of 2 and 3 mm provide more promising fracture resistance than those with intracanal preparations of 4 mm as a way of treating of root-canal-treated maxillary canines. TRINIA endocrowns (2 and 3 mm intracanal preparations) are as promising as fiber posts and all ceramic crowns in terms of fracture resistance. TRINIA endocrowns with 2 mm intracanal preparations are mostly reparable after failure, but those of 3 and 4 mm are mostly irreparable after failure.

Clinical significance: Modifying endocrowns to have intraradicular projections, simulating Nayyar core, may improve the success and longevity of endocrowns in anterior teeth.

Keywords: Endocrowns, Endo-treated-teeth, Fracture resistance, Intraradicular, Maxillary canines.

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Introduction

With the evolution of esthetic and adhesive dentistry, the demand for biomimetic, minimally adhesive restorations, that mimics the natural dental tissues, became a demand from both patient and dentists. Endocrowns are restorations attached to both the pulp chamber and cavity margins, they were first suggested in 1999 Back, Mörmann and Bindle. Which was described as a full ceramic crown cemented to posterior endo-treated-teeth (ETT).[1] Numerous studies indicated endocrowns high success rates and longevity in ETT molars, with fracture resistance higher than that of posts/core/crown.[2–6] Endocrowns offered numerous advantages over posts/cores/crowns; being easier to prepare and retain, needs less clinical visits and time, and superior aesthetics.[7] They recommended it for teeth suffering substantial loss of tooth structure with reduced interocclusal space. This would make it difficult to reach the acceptable crown thickness. Also, endocrowns are indicated for cases with inadequate ferrule, such as mutilated teeth with short clinical crowns.[8,9] Furthermore, they are indicated for teeth that pose a challenge in placing a post, such as teeth with calcified, curved, narrow, or short canals or with fractured files.[8,10]

True, the introduction of endocrowns has come with reasonable solutions, nonetheless, the use of ceramics as a material for endocrowns limits them to posterior teeth, as the markedly higher modulus of elasticity of ceramics would put the anterior teeth at

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risk of fracture, especially with the unfavorable direction of forces in the anterior region.

Canines with extensive tooth loss were previously restored by metal posts or fiber posts and a core, followed by a crown. Both techniques require the removal of substantial amounts of sound dental tissues during post-space preparation, thus weakening the root-tooth complex. They also present a high risk of root perforation. Additionally, the role of a post in the root canal to retain the restoration has been controversial in recent sudies.[11] Clinical studies dating back up to 17 years on crowns cemented on composite core build-ups have failed to prove the advantages of a metallic posts on the survival rate of the teeth.[12,13]

With the evolution of composite-based materials, that combine a tooth-friendly modulus of elasticity with adequate mechanical properties, the hope for using endocrowns in anterior teeth has evolved.[14]

TRINIA (Bicon LLC, Boston, MA) is a milled fiber-reinforced composite (FRC) material that was recently introduced in 2010. It is composed of multi-directional interlacing of fiberglass and resin in several layers.

It has many advantages; it is Biocompatible, modifiable and repairable, light weight and requires no firing. It's supplied in discs or blocks in ivory or pink colors. It was intended to be used by dentists and dental technicians for fabricating copings and frameworks for permanent and provisional crowns, bridges, implant bars and frameworks that can be either cemented or uncemented restorations, such as telescopic restorations. As well as removable partial denture frameworks. It can be easily veneered using composite resin. The suitability of the mechanical properties of Trinia many fixed restorations has been proven in many clinical and laboratory studies.[15–17] Rayyan et al.[17] have validated the use of the material, in short-span bridges, with quite acceptable fracture resistance results that were even comparable to veneered zirconia ones. Moreover, TRINIA's closely matching modulus of elasticity, together with its capability of resin-cementation, offers the monoblock concept of tooth restoration. Opposite to ceramics, due to the opaque nature of TRINIA, color of the resin cement or the cores does not affect the final color of the crown. Add to that, it doesn't need complicated surface treatment.[18–20]

The available data in the literature regarding the mechanical properties of the material would promise optimistic performance when used for endocrown restorations for endodontically treated teeth.[15] The question remains regarding its performance in anterior teeth, with more lateral forces.

Although endocrowns have shown high success rates in molars, there is controversy concerning their use in anterior teeth and premolars. Numerous studies have reported a high failure rate in premolar endocrowns compared to those in molars.[21–23] This is may be due to the reduced space of the pulp chamber, which causes a limited bonding area. Also, the greater overall crown height in premolars could cause a higher leverage effect that results in fracture, especially with non-axial forces, which are more concentrated on premolars.[8–10] On the other hand, some studies suggest that premolars and molars have the same clinical performance.[23]

Regarding anterior teeth, they also have also a reduced bonding area, and are subjected to higher non-axial forces.[8,10] Limited studies have examined anterior endocrowns. They suggested that stresses in anterior endocrowns is higher than those with post/core and crown restorations. The decreased number of studies addressing endocrowns in anterior teeth, prevents conclusive results regarding the actual success rate of anterior tooth endocrowns.[22]

In the current articles, the authors tried to decrease the non-axial forces on the anterior teeth by modifying the conventional design of endocrowns and using a resilient shock-absorbing material. Our aim was to compare the fracture resistance of canine teeth restored using TRINIA endocrowns with 3 different types of preparation (2, 3, and 4 intracanal preparations).

Our null hypothesis was that no statistically significant differences would be observed between the tested groups.

Materials and Methods

Study Design

This study is a comparative, randomized, experimental study.

Study Setting

Specimens were prepared at the faculty of dentistry, Sinai University simulation laboratories. The study design was audited and accepted by the Sinai University Institutional Review Board (IRB) Committee, with approval "SU.REC 2024(NO.1H)". The study was done in 2024 for 3 months.

Calculating Sample Size

The software XLSTAT Premium (Lumivero, Denver, CO 80202, USA) was utilized for sample size calculation (goal power was set to 85% and alpha to 0.05). Consequently, 10 teeth were used for each subgroup, resulting in a total of 30 teeth being used.

Study Sample

Thirty maxillary canines, extracted from humans, were selected for this study. Selection criteria included: Width of tooth cervically was 7.5–8 mm, roots were clear of any caries, resorption or abnormality, with only 1 root canal and finally should be extracted within a period of 6 months. All teeth were visually inspected using loups and light source for any variations. All teeth were cleaned, washed, autoclaved at 121ºC under presser of 15 lbs psi for 20 min and stored in distilled water for 3 days (Flowchart 1).[24]

Specimen Grouping

Each preparation depth (2, 3, and 4 mm) consisted of 10 canines.

Teeth Mounting

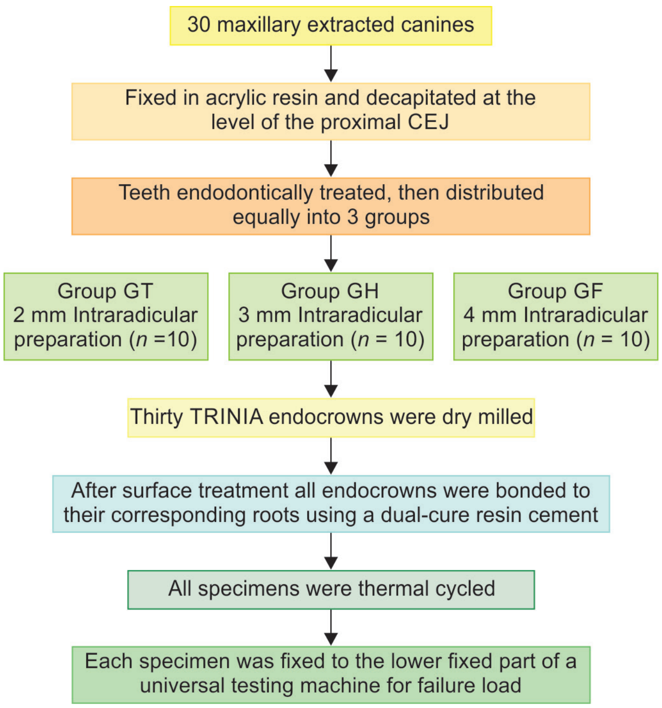
Each tooth was secured in orthodontic acrylic-resin blocks using a custom-built rectangular rubber-mold (25 × 25 × 50 mm). The teeth were held in a vertical position using a paralleling device (af350, Amann Girrbach AG, 6842 Koblach, Austria). Orthodontic Acrylic Resin (Neocryl, Harry J Bosworth, Skokie, IL 60076, USA) was mixed and poured into the mold according to manufacturer recommendations. Teeth were secured in the acrylic resin mix 2 mm above the cemento-enamel junction (CEJ). Teeth were secured in their vertical positions till polymerization of resin was completed.

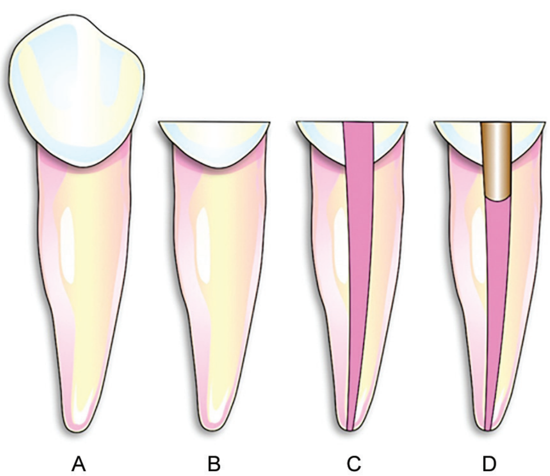
Teeth Preparation (Fig. 1)

Teeth Decapitation

Crowns of collected teeth were cut and removed at the level of the proximal CEJ, the cut starting from the proximal surfaces using a carbide bur (Great white ULTRA 856-016S, SS White, 1145 Towbin Avenue, Lakewood, New Jersey 08701) and then diamond disc

Flowchart 1: Flowchart of study steps





Figs 1A to D: Teeth preparation. (A) Intact maxillary canine; (B) Decapitated canine; (C) Root canal treatment; (D) Intracanal preparation

(NTI Turbo Crown Cutters, Kerr, CH-8302 Kloten, Switzerland) with sufficient water cooling. After crowns were separated and in order to avoid dryness, mounted roots were kept in a 0.9% concentration sterilized saline mixture.

Endodontic Treatment

Two burs were used for the preparation of access cavities: a round bur (Great white #4SL ROUND, SS White, 1145 Towbin Avenue, Lakewood, New Jersey 08701) was used, followed by an ENDO-Z bur (DENTSPLY Maillefer, Oklahoma 74135, USA). Preparation was done under copious water coolant by means of a high-speed cutting. Working length was determined by the size of the 15 K file and by using a periapical radiograph. Ni-Ti Rotary files (ProTaper, Dentsply, USA) reaching size F3 file. Irrigation between files was done using a 4.2% Sodium Hypochlorite solution. Paper points (Ultradent, UT 84095, USA) were used after intermittent irrigation to dry the root canals. Obturation was performed with same-taper single cones (Dentsply, USA) coated with Resin sealer (EndoREZ, Ultradent, UT 84095, USA). A heated instrument was used for removing the extra gutta-percha, while a vertical plunger was used for compacting the coronal part.

Specimens' Classification

Mounted endodontically treated mounted roots were distributed among 3 main groups ($n = 10$) randomly:

- Group (GT): Endodontically-treated canines restored with TRINIA endocrowns with butt-joint finish line and 2 mm intraradicular preparation.
- Group (GH): Endodontically-treated canines restored with TRINIA endocrowns with butt-joint finish line and 3 mm intraradicular preparation.
- Group (GF): Endodontically-treated canines restored with TRINIA endocrowns with butt-joint finish line and 4 mm intraradicular preparation.

Intraradicular Preparation

It was done using a Peeso reamer (NORDIN, CH-1816 Switzerland) size 4 with a rubber stopper consider with butt-margin as reference-point.

- For GT group, 10 roots were prepared with 2 mm intraradicular preparation.
- For GH group, 10 roots were prepared with 3 mm intraradicular preparation.
- For the GF group**,** 10 roots were prepared with 4 mm intraradicular preparation.

Computer Aided Design

Each root face of 30 mounted roots was scanned using an Extra Oral Scanner (EOS) (Vinyl High Resolution, Merz Dental GmbH, Germany). STL files were exported to Exocad software (Exocad GmbH, Germany) to adjust the fitting surface of each STL file according to each scanned root and assign each endocrown design to its root.

TRINIA Endocrowns CAM

All STL files were exported to dry milling machine (CORiTEC, 350i Loader X PRO, imes-icore GmbH, Germany) and endocrowns were milled using TRINIA blanks (Bicon, MA 02130, USA) (Fig. 2). After termination of the milling process, a diamond cutting instrument was used to separate the crowns from the blocks. All milled endocrowns were cleaned using an ultrasonic device and each was assigned to its correspondent root and checked for seating.

Surface Treatment and Bonding Procedures

35% phosphoric acid (Ultra-Etch, Ultradent, UT 84095, USA) was applied for 15 seconds to the prepared root surfaces and intraradicular prepared part, and then rinsed for 60 seconds and dried with air. The bonding agent (Peak Universal bond, Ultradent, UT 84095, USA) was actively applied with a microbrush. The bonding agent was then thinned out using air and then light-cured (Elipar LED Curing Light, 3M, USA) for 20 seconds.

All TRINIA endocrowns were air-particle-abraded (APA) using 50µ Alumina-Oxide powder.[17] Using a microbrush, Silane-coupling agent (Ultradent, UT 84095, USA) was actively brushed on air particle abraded surfaces, then thinned out using jets of oil-free air.

Dual-cured resin cement (PermaFlo DC, Ultradent, UT 84095, USA) was applied on the treated surface of each root and on intaglio surface of its corresponding endocrown. Each endocrown was seated with finger pressure on its corresponding prepared root, and a microbrush was used to remove excess cement. A light cure was used to cure the cement for 20 seconds on each surface of the tooth.

Thermal Cycling

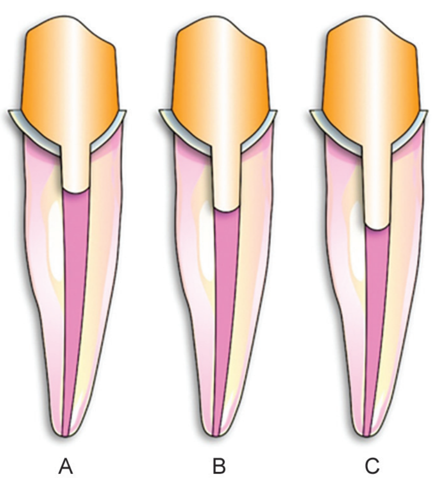
Each specimen was thermally cycled for 5,000 cycles between water bathes of 55 and 5°C with 30 sec dwell time in each bath.[17]

Static Test

Each specimen was fixed at a 45-degree angle onto the lower compartment of the universal testing machine (3345; Instron, Norwood, MA) with a 5 kN load cell. Local stress concentration was prevented by placing a 1 mm-thick folded tin-foil leaf between the palatal surface of the canine core and the loading tip. A 5.8 mm diameter metallic indenter was used for load application, attached to the upper mobile part of the universal testing machine with a crosshead-speed of 0.5 mm/min. A distinct crack sound manifested the failure, as confirmed by a sharp drop in the load deflection curve. The outcome was recorded in Newton.[25]

Statistical Analysis

Descriptive statistics (mean and standard deviation) were used to code and analyze the recorded data for quantitative variables. According to the Shapiro–Wilk test, the data were not found to be normally distributed. Parametric Kruskal–Wallis was used to determine significant differences between groups, and a Mann–Whitney *U* test was conducted to analyze the differences in fracture strength of endocrowns according to different preparation depths.



Figs 2A to C: TRINIA endocrowns. (A) Group GT – 2 mm; (B) Group GH – 3 mm; (C) Group GF – 4 mm

Results

The homogeneity of specimens' results was determined by running Shapiro Wilk test on both groups. Therefore, the statistical analysis implemented can be decided. As a test results the data was not normally distributed.

- **Descriptive Statistics**
  The high mean values of the GH group (647 ± 321.37) were revealed, followed by the GT group (475.60 ± 318.92). The least was group GF (353.90 ± 172.03) (Table 1).
- **Intergroup Statistics**
  Kruskal–Wallis test: Analysis showed significant differences between tested groups ($p = 0.036$) were revealed after the application of the Kruskal–Wallis test (Table 1).
- **Intragroup Statistics**
  Mann–Whitney U test: When comparing GT with either GH ($p = 0.131$) or GF ($p = 0.326$), no statistically significant differences were found. Only a significant difference was seen between GH and GF ($p = 0.0102$) (Table 2).

Discussion

This study was conducted in an attempts to decrease the non-axial forces on the anterior teeth by modifying the conventional design of endocrowns and using a resilient shock-absorbing material.

In this current study, TRINIA CAD/CAM blocks were used, which are made of a multi-directional interlacing of fiberglass and resin in multiple layers. Dentists can use TRINIA for multiple purposes, such as making substructures or frameworks for permanent and transitional posterior or anterior crowns, copings, or bridgework. The material is light-weight, durable, resilient, biocompatible, and adjustable. The high flexural and compressive characteristics give it a unique mechanical property. In addition, no firing is required.

In vitro study was done to overcome limitations related to clinical testing, like individual variation in a creation-controlled environment.[26]

Human teeth were chosen to be used in this study instead of metal, plastic, or bovine teeth in order to mimic the actual clinical situation by their strength, bonding features and elasticity modulus. The teeth were selected with attention in order to have similar sizes, the canines were chosen to be approximately similar in form and dimensions with only 5% accepted deviance to prevent results contamination.

The selection of endocrowns to be on maxillary canine teeth in this study is because, compared to molar teeth, they showed non-satisfactory performance when it comes to bonding strength and occlusal forces, in a previous study. The reasons could be due to the fact that canines have a small pulp chamber added to that, restorative materials that were used had low bonding features to teeth.

Table 1: Descriptive statistics of fracture strength and fracture analysis of endocrown restorations with Kruskal–Wallis test results

Preparation depth	*N*	*Mean*	*Std. dev.*	*Std. error*	*Min.*	*Max.*	*Kruskal–Wallis test*
GT: 2 mm intraradicular preparation	10	475.60	318.92	100.85	142	1057	–
GH: 3 mm intraradicular preparation	10	647.00	321.37	101.63	113	1343	$p = 0.036$
GF: 4 mm intraradicular preparation	10	353.90	172.03	54.40	104	656	–
Total	30	–	–	–	–	–	–

Table 2: Mann–Whitney *U* test results

Preparation depth (I)	*Preparation depth (J)*	*Mean difference (I–J)*	*U-value*	*p-value*
GT	GH	–171.40	30.0	0.131
	GF	121.70	37.0	0.326
GH	GF	293.10	16.0	0.0102

Paralleling device was utilized during the mounting of teeth in acrylic blocks to make sure that all teeth were placed vertically so that the applied force direction would be standardized for all.

Teeth decapitation was done using a special jagged-teeth turbo carbide bur for easy, clean cutting to prevent burns and damage to the root of the face.

A combination of Nayyar core and endocrown design with part projecting into the canal was suggested for more possible resistance and retention of design.

Endocrowns were cemented using PermaFlo DC (Ultradent, UT 84095, USA), a dual-cure adhesive resin cement.[27] A protocol of a total etch and adhesive cement were used for cementation to provide high retention.[28]

When comparing the depth and design and in the current study, GH had a higher mean fracture resistance score than GT maybe due to having deeper intraradicular preparation (2 mm for GT, 3 mm for GH) so we have a greater surface area needed for bonding, stress distribution and retention.

The result for GF, scoring the lowest fracture resistance, was unexpected and is probably due to increased constriction in the root canal of the canine at the 4 mm depth, which led to more removal of tooth structure and thinning of the root in this area after the intracanal preparation with the Peeso Reamer (Maillefer Peeso Reamers) size 4, and that caused weakening of the root, which may have led to the lowest fracture strength.

Mann–Whitney *U* test revealed that significant differences between GT and both GH ($p = 0.025$) and GF ($p = 0.025$). Whereas, GH and GF showed no significant differences ($p = 1.00$), This may be related to the depth of preparations intraradicularly, the highest repairing possibility was found in GT because the intraradicular endocrown projection was only 1 mm, so debonding could occur between the endocrown and the tooth without causing root fracture. In GH and GF the debonding caused root fractures and complicating the reparability situation.

GH scored a mean value of 647 N and GT scored a mean value of 475.6 N; those results are higher than those of ET canines restored with fiber-reinforced posts and ceramic crowns, whether a 2 mm ferrule height was present or absent, which are respectively 469 N with ferrule and 451 N with no ferrule.[28]

Our result's accordance to that of Cruzado-Oliva et al.[29] who they concluded that 3 mm endocrown is subjected to fewer stress than 1 mm endocrown 1 and 5 mm endocrowns projections.

On the contrary, many articles tied decreased stress to depth in a linear manner. Assuming that the longer the extension, the fewer stresses, claiming that the decrease in stresses is due to contact surface area.[30–33] Unfortunately, the deeper the preparation, the more removal of the tooth structure is removed. However, in one study, it was found that teeth resorted with endo crowns had similar fracture resistance as those rested using glass-fiber posts, assuming that endocrowns would behave as short posts.[34] Contrary to other studies, which found that the depth of the endocrown preparation is not directly related to fracture resistance, or the stress's distribution.[31,32]

One drawback of this study is the high standard deviation resulting in inhomogeneous data and thus the use of Kruskal–Wallis test instead of one-way ANOVA. This may be due to the use of natural teeth, with their high variability. Future tests utilizing resin teeth are highly recommended to either support or reject our findings. A second recommendation is comparing Trinia to PEEK and ceramic endocrowns. Testing ferrule effect would also be beneficial.

Clinicians should carefully evaluate the pros and cons of extending deeper into the root canal so as to remove more valuable tooth structure. Shifting to resilient and more biomimetic materials could evade the tooth's higher stresses and serve better for the longevity and success of the restoration.

Since the results between the tested groups were statistically significant, the null hypothesis was rejected.

Conclusion

Within the limitation of current study, the following could be concluded:

- TRINIA endocrowns with 2 and 3 mm of intracanal preparations dispense promising resistance to fracture than those with 4 mm intracanal preparations as a treatment modality of maxillary canines endodontically treated.
- TRINIA endocrowns with 2 mm intracanal preparations are mostly reparable after failure, but those of 3 and 4 mm are mostly irreparable after failure.
- TRINIA based restorations may present a viable treatment option for endocrowns in anterior region.

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