

Effect of Full Coverage, Endocrowns, Onlays, Inlays Restorations on Fracture Resistance of Endodontically Treated Molars

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Abstract

Purpose: This in vitro study compared the fracture resistance of endodontically treated first maxillary molars restored with fiber posts (FRC Postec Plus-Ivoclar Vivadent) and lithium disilicate ceramic (IPS e. Max Press/ Ivoclar Vivadent) full crowns, endocrowns, onlays and inlays with respect to the observed failure modes.

Materials and Methods: Fifty sound human maxillary first molars were selected, prepared and divided into five groups. Group 1 was left intact (control), all other groups were endodontically treated, group 2 was restored with lithium disilicate full crown. Group 3: Endocrown restorations. Group 4: Onlay restorations. Group 5: Inlay restorations. All restorations were fabricated from lithium disilicate according to manufacturer instructions. Fracture resistance (N) was measured using a universal testing machine parallel to the long axis of tooth till failure. Fractures were divided into 2 groups restorable and non-restorable. The mean loads of failure of each group were statistically compared using ANOVA $p < 0.001$. Chi-square tests were used to compare frequencies of favorable and unfavorable failure among groups.

Results: Mean failure loads were :group 1:985 N, group 2:1076 N, group 3:989 N, group 4:908 N and group 5:638 N respectively. As regard mode of failure: group 1:40% restorable, group 2:90% restorable, group 3:80% restorable, group 4:80% restorable and group 5:30% restorable.

Conclusions: 1-Full coverage, intact teeth and endocrowns showed the highest fracture resistance respectively with no significant difference. 2-Onlays then inlays showed the least fracture resistance. 3-Full coverage group showed the best mode of failure and inlay showed the worst.

Introduction

During the last 30 years ,evolution of adhesive philosophy in dentistry and the high bonding performance achieved by modern adhesive systems have gradually changed the dogma of devitalized tooth should be restored with post, core and crown. Adhesion ensures sufficient material retention without the need of aggressive macroretentive technique [1].

The endocrown is a total porcelain crown fixed to a devitalized tooth, which is anchored to the internal portion of pulp chamber and cavity margins, thus obtaining macromechanical retention (provided by the pulpal walls) and microretention (by using adhesive cementation) [2].

Onlay is an extra-coronal restoration usually involving same area as inlay restoration and portion of outer cuspal slope, it is indicated in cases of steep cuspal inclines as wedging force tends to direct forces not parallel to the long axis of tooth [3]. The versatile inlay and onlay restorations require meticulous care in preparation, but when properly designed are extremely useful as durable restorations, able to withstand occlusal forces and more compatible with soft tissues as can be seen in gingival and subgingival margins [3].

New materials and therapeutic options based entirely on adhesion are nowadays available as direct composite and endocrown restorations. They allow performing a more conservative, faster and less expensive dental treatment. With the advent of adhesive dentistry, it has become acceptable to restore teeth with extensive coronal destruction by performing endocrowns without using posts and by using extension of the pulp chamber as a retentive resource [4-6].

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These restorative procedures were made possible by the development of acid etchable ceramics (such as leucite and lithium disilicate based ceramics), dentinal adhesives and resin cements [7].

The first study published on endocrown was conducted by Pissis [6] in 1995. He described the ceramic monoblock technique for teeth with extensive loss of coronal structure. However, it was Bindl and Mormann [8] who named this restorative procedure "endocrown" in 1999. Endocrowns are especially indicated in cases of molars with short, obliterated, dilacerated or fragile roots. They may also be used in situations of excessive loss of coronal dental tissue and limited interocclusal space, in which it is not possible to attain adequate thickness on the ceramic covering on the metal or ceramic substructures [9].

Endodontic procedures have been shown to reduce tooth stiffness by only 5% whereas an MOD preparation reduces tooth stiffness by 60% [10]. In a large clinical study the fracture rate for uncrowned molars was double that restored with crowns. The success rate for maxillary molars dropped from 97.8% for those with crowns to 50% for those without crown [11].

The tooth structure remaining after endodontic therapy also exhibits irreversibly altered physical characteristics. Changes in collagen cross linking and dehydration of the dentin result in 14% reduction in strength and toughness. Maxillary teeth are stronger than mandibular teeth and mandibular incisors are the weakest [12].

The internal moisture loss is approximately 9% and is greater in anterior than posterior ones. This combined loss of structural integrity, loss of moisture and loss of dentin toughness compromises endodontically treated teeth [13].

The greatest bite force was found in the first molar region, whereas at the incisors it decreased to only about one third to one fourth that in the molar region. In previous studies, mean values for the maximal force level in the molar region have reached 847N [14].

For the incisal region, smaller values ranging from 108 to 299N have been reported [15]. Men often achieve significantly greater bite forces than women [16]. The present in vitro study aimed to make a comparison between different restoration designs regarding fracture resistance and mode of failure.

Materials and Methods

Specimen selection

50 sound human maxillary first molars with 3 separated root canals were selected and used in this study. After soft tissue removal, the teeth were stored in 5% formal/saline for 2 hours then cleaned and transferred to distilled water to prevent desiccation during storage. The average buccopalatal and mesio-distal mean widths were 10.71 ± 0.63 mm and 9.30 ± 0.55 mm, respectively. Teeth falling below or above size limits were excluded.

The roots of teeth were embedded parallel to the long axis of the teeth into self cure acrylic resin (Acrostone, WHW Plastics, East Yorkshire, UK) up to 2 mm below cement-enamel junction (CEJ) using rings. The teeth were then randomly allocated to five groups (n=10). For each tooth an impression was made using a

heavy body polyvinyl siloxane impression material (Imprint, 3M ESPE), which was sectioned and used as an anatomical guide during tooth reduction.

Root canal preparation: In group 1, no cavities were prepared. In group 2 through 5 triangular shape access cavity was prepared for endodontic treatment. The teeth were endodontically instrumented with K files (Union broach) to an apical size 35 for buccal canals and 45 for palatal canals using step back technique, irrigation with 1 ml of chlorhexidin preceded each file introduced into the canal.

Following biomechanical preparation, the prepared teeth were obturated with lateral condensation technique using gutta-percha (Diadent Group International Inc., chongju; De-trey, Konstaz, Germany) AH plus endodontic sealer (Dentsply; De Trey, Konstanz, Germany) using lateral condensation technique.

Canal preparation: Root canal is prepared for prefabricated glassfiber reinforced post (FRC Postec Plus-Ivoclar Vivadent, Shaan Liechtenstein, Switzerland). Corresponding diameter of post were selected 1.2 mm to accommodate the palatal canal of teeth. Gutta percha was removed to within 3mm of working length with a size 3 reamer. A grinding machine (grit 500) was used to standardize the length (12 mm) of the prefabricated posts.

MOD cavity preparation: According to previous studies, mesio-occlusodistal (MOD) cavities were prepared using a 245 bur (SS White, Lake wood, NJ,USA) with water spray. A new bur was used every 5 teeth. One operator completed all the preparations. The buccolingual width occlusally was 3 mm, height of the axial wall was 2 mm, width and depth of gingival wall were 4.0 mm and 1.5 mm respectively using rubber impression index as reference.

All internal line angles were rounded. Prior to actual cavity preparations for MOD inlays the outline of each cavity was drawn on the surface of the tooth as a preparation guide with a 6° divergence of the walls of occlusal and proximal boxes. Group 1; teeth remained untreated (control). In group 2, a full shoulder margin was prepared. In group 3, pulp chamber was prepared with anatomic configuration of the chamber with an internal taper of 8 to 10 degrees.

For group 4; a 2 mm reduction was performed in buccal and palatal cusps. For endocrown preparation the pulp chamber was prepared according to previous study with the same diamond coated tip to the limit of the anatomic configuration of the chamber with an internal taper of 8 to 10 degrees. The chamfered walls and margins were smoothed with a fine- grained tapered trunk diamond coated-tip #4138 at low speed.

Restorative procedures: The following restoration methods were employed:

Group 1: No restoration, intact molars (control).

Group 2: Through 5 received glass fiber post except group 3, and the following restorations were used:

Group 2: Full coverage all ceramic restorations.

Group 3: Endocrown all ceramic restorations.

Group 4: Onlay all ceramic restorations.

Group 5: Inlay all ceramic restorations.

Specimens preparation: An impression was taken for each sample (polyvinyl siloxane impression material; Imprint 3M Espe, USA) working dies were made with special refractory die materials. The restoration was fabricated from lithium disilicate-based ceramic (IPS E Max Press, Ivoclar Vivadent). The technique consists of injecting the melted ceramic pellet into a lining mold fired in a furnace at a temperature of 850°C, in accordance with the manufacturer’s instructions.

The internal surface of the piece was treated in accordance with the technique recommended for lithium disilicate-based ceramics: application of 10% hydrofluoric acid (IPS ceramic etching gel-Ivoclar Vivadent) on the internal surface for 20 seconds, washing with water/air for 30 seconds, application of the silane coupling agent (Silane Universal - Ivoclar Vivadent) for 1 minute, and application of a thin coat of the adhesive agent (Adper Scotchbond Multi-Purpose, 3M Espe, Saint Paul, MN,USA), using a disposable applicator, followed by a light air jet and light activation for 20 seconds.

The tooth was etched with 37% phosphoric acid (3 M Espe, USA), for 15 seconds, with the application starting from the margins in enamel. Afterward, the tooth was washed with abundant water, and an air jet was applied for 20 seconds; the preparation was dried, keeping the dentin moist, and the activator, primer, and catalyzer of the adhesive system (Adper Scotchbond Multi-Purpose, 3M Espe, USA) were applied, waiting 15 seconds between each application (Tables 1 and 2).

Restorations were seated under a 5Kg constant load for 10 minutes. after removal of excess cement, half of specimens were thermocycled (5000 cycles, 5° to 55°C; dwell time: 60 seconds, transfertime; 12 seconds) then stored at 37°C in distilled water for 24 hours before testing.

Fracture resistance test: All specimens were mounted in a jig that allowed loading with long axis of the roots in a universal testing machine (Instron S 500 R England) with cross head speed of 1mm/min. All crowns were loaded until catastrophic failure occurred (Figure 1) and the testing machine automatically recorded the fracture force (Newton). Fractures were divided into

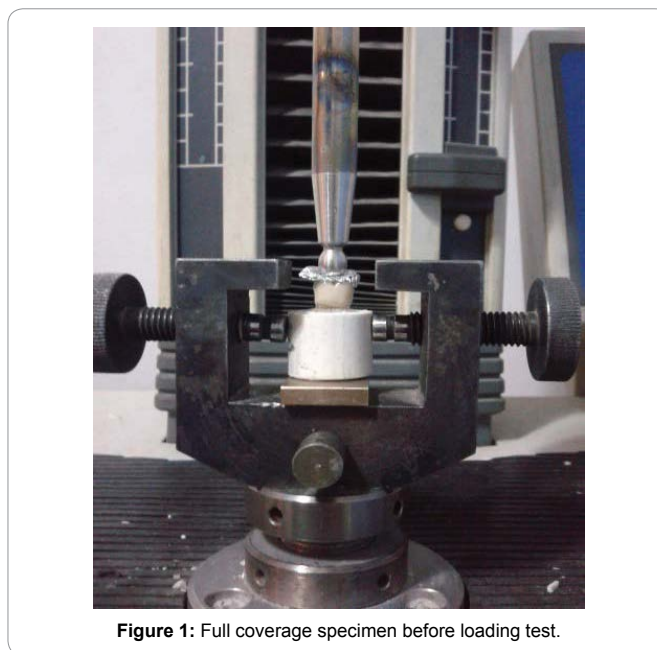


Figure 1: Full coverage specimen before loading test.

two groups based on the extent of each fracture: (1) Restorable: fractures stopping higher than 1 mm below the embedding resin surface; and (2) unrestorable fractures = fracture stopping lower than 1 mm below the embedding resin surface.

Statistical methods

One way analysis of variance (ANOVA) was used to compare mean failure loads $p < 0.001$. Chi-square tests were used to compare frequencies of favorable and unfavorable failures among groups $p = 0.017$.

Results

Mean failure loads for the 5 tested groups were as follows: group 1:985 N, group 2:1076 N, group 3:989 N, group 4:908 N and group 5:638 N. As regard mode of failure, group 1 showed 40% restorable, group 2 showed 90% restorable, group 3 showed 80% restorable, group 4 showed 80% restorable and group 5 showed 30% restorable (Graph 1 and 2).

Study groups	Mean	Std. Deviation	Minimum	Maximum
Intact	985.60 (ab)	69.26	885.00	1105.00
Full Crown	1076.00 (a)	131.70	909.00	1276.00
Endocrown	989.20 (ab)	109.07	851.00	1187.00
Onlay	908.90 (b)	124.55	771.00	1113.00
Inlay	638.10 (c)	77.61	538.00	770.00

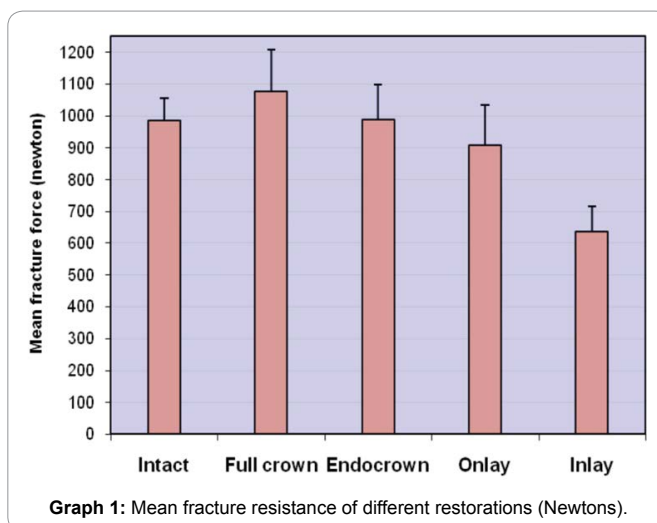
p value < 0.001, groups sharing same letter are not significantly different

Table 1: Mean fracture resistance (newton) and its standard deviation in different groups.

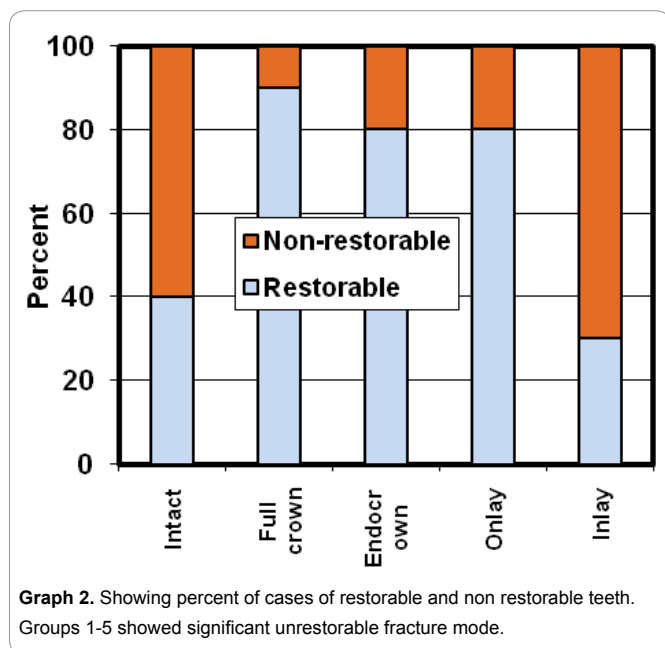
Study groups	Fracture mode			
	Restorable		Unrestorable	
	Count	Row %	Count	Row %
1.Intact	4	40.0%	6	60.0%
2.Full Crown	9	90.0%	1	10.0%
3.Endocrown	8	80.0%	2	20.0%
4.Onlay	8	80.0%	2	20.0%
5.Inlay	3	30.0%	7	70.0%

P = 0.017 Groups 1-5 showed significant unrestorable fracture mode.

Table 2. Showing number and percentage of restorable and non restorable teeth.



Graph 1: Mean fracture resistance of different restorations (Newtons).



Discussion

There is no consensus regarding the procedure that gives the greatest success in restoration of endodontically treated posterior teeth. It seems that the amount of preserved coronal tooth structure has the most significant influence on the long-term survival of these teeth.

Fracture strength of materials depend on several factors, including the elastic modulus of supporting substructure, properties of luting agent, thickness of restoration and the preparation design. In this study design of preparation is the affecting factor.

Bonded restorations with full occlusal coverage are proved to have a beneficial effect on fracture strength endodontically treated teeth compared to simple MOD restorations [18-20]. The main reason is that bonded overlays show a more homogeneous distribution of biting forces during function. Moreover, some studies show a certain protective effect of these restorations against irreversible fractures [20]. However, these results are in contrast with other *in vitro* tests where the occlusal coverage configuration has no influence on fracture strength of ETT [21].

Patterns of fracture recorded in group 1 and 5 are almost typical; deep, oblique or vertical root fractures leaves the tooth unrestorable requiring extraction, smaller number of catastrophic fractures were observed in groups 2, 3 and 4. An intact root theoretically allows the repeated restoration of the tooth. However, this requires removal of the fracture post from the root canal, which may not always be successful [22,23].

Worst results of inlay restorations is attributed to geometric form of preparation that exert a wedging force acting to split the tooth when under occlusal stress [3]. Meanwhile, onlay and full coverage direct the force along the long axis by overlaying the cusp tips and a portion of buccal and lingual surface thus opposing the wedging action created by internal design of restoration [24].

Resin bonded all-ceramic restoration maintain the

biomechanical integrity of the compromised structure of non-vital posterior teeth. The number of adhesive bond interfaces is reduced, thus making the restoration less susceptible to the adverse effects of degradation of the hybrid layer [25].

Endocrowns are relatively new, and few professionals feel confident about performing these procedures. Nevertheless, they are easy and quick to perform, compared with traditional single crowns with posts and cores [7,26]. The clinical procedure that involves the fabrication of these restorations, compared with the fabrication of crowns with cores or posts, may be considered less complex, more practical, and easier to perform. The protocol establishes a preparation with expulsive leveling of the pulp chamber walls, followed by sealing of the root canal entrances and cervical margins in a chamfer design [27,28].

Sometimes it is necessary to fill irregularities in the pulp chamber walls with resin composite in order to remove retentive areas that prevent sliding and adjustment of the piece. The internal portion of the endocrown, projected toward the inside of the pulp chamber, is responsible for the mechanical microretention [8-29]. By dispensing with the use of an intraradicular post and maintaining the seal provided by the endodontic filling material, an endocrown allows minimal tooth wear, and thus strengthens the tooth, since it helps preserve sound dental tissue and root canal structures [30].

In 2012, Biacchi and Basting [28] observed greater resistance to compression forces of endocrown restorations, compared with traditional crowns supported on fiber posts, when these restorations were made with lithium disilicate ceramic. The limitation for performing this procedure may be restricted to the ceramic material, which must be an acid etchable ceramic in order to obtain the bond to tooth preparation by means of an adhesive cementation system, and, consequently, ensure stability of the piece in the preparation. Pressed or machined ceramics, especially those reinforced with lithium disilicate, appear to be the best option [31,32].

Conclusions

Within limitations of this study the following conclusions can be drawn:

1. Full coverage, intact teeth and endocrowns showed the highest fracture resistance respectively with no significant difference between them.
2. Onlays then inlays showed the least fracture resistance respectively.
3. Full coverage group showed the best mode of failure and inlay showed the worst.

Clinical implications

1. Bonded restorative materials as acid etchable ceramics (lithium disilicate) has high mechanical strength and esthetic appearance similar to enamel.
2. Endodontically treated molars with intact buccal and lingual walls and weak cusps, ceramic onlay is a good treatment modality binding weak cusps together.
3. Endocrown is a favorable treatment option for severely damaged endodontically treated molars.

4. MOD inlay restorations are contraindicated in posterior teeth with steep cusps due to wedging effect.

Conflict of Interest

No conflict of interest.

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